United States Department of Agriculture

Animal and Plant Health Inspection Service

# National Boll Weevil Cooperative Control Program

## Final Environmental Impact Statement—1991

## Volume 1

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# Summary

## Overview

This programmatic environmental impact statement (EIS) describes alternatives for the National Boll Weevil Cooperative Control Program, in cooperation with the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS). Individual control methods and integrated, programmatic alternatives that could be used in boll weevil control programs are analyzed in detail. Under the preferred alternative, eradication with full Federal involvement, would entail eradication (or elimination) of boll weevil populations across the Cotton Belt of the United States. Table S-1 indicates control methods available for use in this and other program alternatives.

This EIS also describes the environment that may be affected by the control program and discusses the potential environmental consequences and economic costs of implementing any of the program alternatives. Potential environmental consequences of the available control methods are also described in detail.

This EIS is prepared pursuant to the requirements of the National Environmental Policy Act (NEPA), the Council on Environmental Quality (CEQ) regulations for implementing NEPA, USDA procedures for implementing NEPA (7 CFR 1(b)), and the APHIS guidelines for implementing NEPA (44 FR 50381-50384 and 44 FR 51272-51274). The EIS also provides the basic background information needed for the "tiering" of future project-specific analyses and site-specific environmental assessments in accordance with the CEQ regulations for implementing NEPA (40 CFR 1502.20 and 40 CFR 1508.28). Should any future cooperative agreements or treatments funded in whole or in part by APHIS require an environmental assessment, that assessment can incorporate by reference the findings of this EIS and then concentrate only on the relevant issues of that specific site or State.

Public participation has been an integral part of the preparation of this EIS. In accordance with 40 CFR 1501.7 and 1506.6, scoping comments were solicited both by mail and at three public scoping meetings held in the summer of 1988 in Montgomery, Alabama; Lubbock, Texas; and Phoenix, Arizona. Commenters included representatives of Federal, State, and local governmental agencies; public interest groups; environmental groups; industry groups; and concerned individuals. The issues and concerns of the public, along with the programmatic requirements of APHIS, were analyzed and used to develop a range of alternatives and to evaluate these alternatives. The issues and concerns of the public were also used in assessing the impacts of the various alternatives, in developing mitigation procedures to be incorporated in the alternatives, and in selecting the preferred alternative. The public was invited to review and comment on the draft EIS and its supplement before completion of this final EIS. Comments from Federal, State, and various local groups with an interest in the boll weevil program were received.

**Table S-1. Use of Control Methods in Program Alternatives**

| Control method | No action[a] | Eradication | | Suppression | |
|---|---|---|---|---|---|
| | | Full | Limited | Full | Limited |
| **Cultural[b]:** | | | | | |
| Short-season techniques | 2 | 2 | 2 | 2 | 2 |
| Stalk destruction | 2 | 1 | 1 | 2 | 2 |
| Trap cropping | 2 | 3 | 3 | 2 | 2 |
| Crop rotation | 2 | 2 | 2 | 2 | 2 |
| Production limitations | 3 | 2 | 2 | 3 | 3 |
| **Mechanical** | 3 | 2 | 2 | 3 | 3 |
| **Sterile insect technique** | 3 | 2 | 2 | 3 | 3 |
| **Chemical** | 1 | 1 | 1 | 1 | 1 |

[a] Control methods that may be used by growers only.
[b] Use of several of these cultural controls must be mandated by State agricultural agencies.

Legend: 1 = Generally incorporated into control program.
2 = Could have limited use in control program, depending on efficacy and cost.
3 = Not expected to be used in control program.

The issues and concerns raised in these comments have been addressed in this final EIS. A summary of the public participation in this EIS can be found in appendix C, and detailed comments and responses can be found in appendix D.

## APHIS' History in Boll Weevil Control

Since the boll weevil first entered the United States in the late 1800s, it has caused an estimated $12 billion in losses to the Nation's economy. In 1980 the boll weevil was directly responsible for yield losses on about 7 million of the 14 million acres of cotton planted, despite the use of the best available control practices. Between 1981 and 1984, total economic damage—including control costs—from the boll weevil averaged an estimated $145.1 millon annually. Continuing crop losses from the boll weevil and the resultant high annual control costs are major contributors to the high cost of producing cotton in the United States.

Cotton is the fourth most valuable crop in the United States, after corn, soybeans, and wheat. Although cotton represented only 4.6 percent of the total crop revenue in the United States in 1986, it represented one-quarter to one-third of all crop revenue in many of the cotton producing States. The total value of the 1986 cotton crop was approximately $2.7 billion.

The migratory nature of the boll weevil necessitates areawide, interstate cooperation for control programs to succeed. Since the early 1900s, growers, growers' associations, and States have proposed and experimented with a variety of control methods. However, since the early 1970s, there has been general acceptance of the need for a beltwide strategy for the control of the boll weevil. A 2-year Pilot Boll Weevil Eradication Experiment between July 1971 and July 1973 in Mississippi, Louisiana, and Alabama was a cooperative effort involving Federal and State agencies and growers' associations. The success of this program led to two additional 3-year field trials (a boll weevil eradication trial in North Carolina and Virginia and an optimum pest management trial in Mississippi) from 1978 to 1980. Current APHIS coordinated boll weevil cooperative control programs include the Southeast Boll Weevil Eradication Program (composed of approximately 640,000 acres of cotton in Florida, Georgia, South Carolina, and the southern counties of Alabama), the West Texas Containment Program (composed of approximately 270,000 acres of cotton in the High Plains and the Rolling Plains of West Texas), and the Southwest Boll Weevil Eradication Program (composed of approximately 420,000 acres of cotton in central Arizona and Northwest Mexico).

APHIS cooperative management programs are authorized by the Incipient and Emergency Control of Pests [Act] (1937), the Organic Act of the Department of Agriculture (1944), the Cooperation with State Agencies in the Administration and Enforcement of Certain Federal Laws Act (1962), and the Food Security Act of 1985. In addition, each

State has basic pest control authority, which authorizes participation in cooperative pest management programs.

The National Boll Weevil Cooperative Control Program consists of four basic functions: mapping cotton-growing areas and surveying boll weevil populations, establishing and implementing control procedures, monitoring, and maintenance of eradicated areas. The degree of APHIS participation in cooperative boll weevil control activities depends on the alternative selected. Table S-2 summarizes the nature of APHIS participation under each alternative and the estimate of APHIS costs associated with each alternative.

## Control Methods and Alternatives Considered

Control methods, currently used by APHIS and suggested by commenters during the scoping process included cultural control, mechanical control by mass trapping, sterile insect release, biological control by predators and parasites, and chemical control.

Program alternatives recommended by commenters during the scoping process fell into the following categories:

- Follow current grower practices (no APHIS control program)
- Initiate a beltwide eradication program
- Initiate a beltwide suppression program
- Initiate a nonchemical program.

### Alternatives and Control Methods Eliminated From Detailed Study

In addition to examining the control methods and program alternatives suggested in the scoping process, APHIS conducted an extensive search of the scientific literature to identify all available methods for boll weevil control. APHIS evaluated control methods and program alternatives in terms of efficacy, commercial availability, beltwide applicability, and cost. Control methods or program alternatives that failed to meet the standards of these criteria were eliminated as impractical for boll weevil control at the programmatic level. Control methods eliminated from detailed study were biological control using introduced predators and parasites and resistant plant varieties. The nonchemical, Integrated Pest Management (IPM), and direct subsidy program alternatives were also eliminated from detailed study. The rationale for eliminating alternatives and methods from detailed study is discussed in chapter 2 of the EIS.

### Alternatives Selected for Detailed Analysis

Cooperative control program alternatives have been grouped into three broad categories for detailed analysis: no action (no APHIS participation in a control program), a beltwide eradication program, and a beltwide suppression program. Under the eradication and suppression programs, APHIS considered both full and limited Federal involvement. This section describes the five program alternatives; table S-1 illustrates how various control methods could be integrated into each program alternative.

**Table S-2. Comparison of National Boll Weevil Cooperative Control Program Alternatives**

| | | Eradication | | Suppression | |
|---|---|---|---|---|---|
| Criterion | No action | Full Federal involvement (preferred alternative) | Limited Federal involvement[a] | Full Federal involvement | Limited Federal involvement[a] |
| Purpose | NA | Eradicate (eliminate) the boll weevil from the U.S. Cotton Belt. | | Bring boll weevil population below levels expected to result in significant economic loss. | |
| Years of APHIS involvement per increment | NA | 3.5 | 3.5 | Indefinite | 3.0 |
| Duration of program across Cotton Belt (years) | NA | 22 | 22 | Indefinite | 17 |
| APHIS cost (millions of dollars) | 0 | 173 | 103 | 1,616 | 275 |
| APHIS personnel requirements | Substantial reduction | Moderate increase | Moderate reduction | Substantial increase | Increase |
| State cooperation | NA | Mandatory State cooperation through enabling legislation; 2/3 vote by growers in referendum. | | Mandatory State cooperation through enabling legislation; 2/3 vote by growers in referendum. | |
| Potential grower acceptance | Low-moderate | High | High | Low | Low |
| APHIS supervision of pesticide application | No | Yes | No | Yes | Yes (3 years) |
| Cumulative acreage (millions) controlled by program | 0 | 49 | 49 | 594 | 102 |

**Table S-2. Comparison of National Boll Weevil Cooperative Control Program Alternatives (continued)**

| Criterion | No action | Eradication: Full Federal involvement (preferred alternative) | Eradication: Limited Federal involvement[a] | Suppression: Full Federal involvement | Suppression: Limited Federal involvement[a] |
|---|---|---|---|---|---|
| Risk to human health | Potential for slight to significant risk of adverse health effects. Degree of risk dependent on choice of chemical. | Potential for slight to significant risk of adverse health effects. Degree of risk dependent on choice of chemical. Mitigation measures and operating procedures reduce risk to acceptable levels. | | Potential for slight to significant risk of adverse health effects. Degree of risk dependent on choice of chemical. Mitigation measures and operating procedures reduce risk to acceptable levels. | |
| Risk to nontarget species | Potential for some adverse effects on nontarget species. Degree of risk dependent on choice of chemical. | Potential for some adverse effects on nontarget species. Degree of risk dependent on choice of chemical. | | Potential for some adverse effects on nontarget species. Degree of risk dependent on choice of chemical. | |
| Potential for environmental degradation | Greater potential for cumulative effects in the long term. | Negligible potential for cumulative effects in the long term. | | Greater potential for cumulative effects in the long term. | |

[a] Federal ability to ensure mitigation is limited under these two alternatives.
[b] Although this suppression alternative would have no termination date, the anticipated APHIS cost for the first 30 years of the program is $1,254 million.
[c] Although this suppression alternative would have no termination date, the cumulative acreage controlled for the first 30 years of the program is 594 million acres.

Note: NA = not applicable.

### Alternative 1—No Action

Under the no action alternative, APHIS would not fund or participate in any program to control the boll weevil in the Cotton Belt. Although other agencies within USDA may continue to offer technical assistance, any active control of the pest would be left to the discretion of Cotton Belt States, growers' associations, and individual cotton growers.

NEPA regulations require an agency to consider the no action alternative, even if an agency is under a court order or legislative command to act (40 CFR 1502.14). The analysis of the no action alternative provides a benchmark or baseline against which the effects of the other alternatives can be measured. Thus, for the purpose of establishing a baseline for the analysis, it is assumed that APHIS would not participate and that current practices by States, growers' associations, and individual cotton growers would continue. These groups may use chemicals that differ in toxic properties or require different application rates or frequencies than those proposed for use by this program. These groups are not subject to environmental analysis requirements or adherence to mitigation measures and operational procedures designed to minimize adverse effects.

Although most growers rely on chemical methods, many also practice cultural control methods (such as short-season techniques, stalk destruction, trap cropping, and crop rotation) to reduce the number of required chemical treatments. Mechanical controls and sterile insect techniques are not included in current grower practices because of the inability of either method to control large populations and the expense of rearing, shipping, and releasing sterile weevils.

### Alternative 2—Beltwide Eradication Program

The beltwide eradication program could incorporate in varying degrees all of the control methods analyzed in this EIS: cultural, mechanical, sterile insect, and chemical control methods. Two levels of Federal involvement are analyzed.

***Full Federal Involvement (Preferred Alternative).*** Under this eradication alternative, program cooperators would eradicate (eliminate) the boll weevil from cotton-producing areas of the United States. For the purposes of this program, the goal of eradication will be considered accomplished when boll weevil populations are reduced to undetectable levels across the Cotton Belt. Program cooperators would conduct coordinated eradication programs in conjunction with cooperating States, cotton producers, and other agencies; maintain buffer zones between eradicated areas and infested regions, and encourage the use of cultural control methods. This would enhance the grower's ability to use beneficial insects for controlling secondary pests and would eliminate the need for chemical treatments to control boll weevils.

All cotton acreage in the Cotton Belt would be included in the eradication program, although only infested acres would receive treatment. Program cooperators would use an integrated control approach in choosing control methods. The selection of a particular control method or combination of methods on an individual site would take into consideration several factors, including variations in weevil biology, availability of overwintering sites, weather patterns, and potential impacts on sensitive areas. The integrated control approach used by program cooperators would include the following program components: (1) field mapping and systematic pheromone trapping to detect and delimit (define the extent of) boll weevil pest populations; (2) mandatory participation by cotton growers following a positive grower referendum; (3) judicious use of available control measures in response to existing pest conditions and environmental concerns; and (4) limitation of control applications to infested acreage.

Under the preferred alternative, chemical control by foliar application of malathion, azinphos-methyl, diflubenzuron, and methyl parathion would be available for use in accordance with standard operating procedures and mitigation measures described in chapter 2 of the EIS. Two other pesticides, chlorpyrifos and propoxur, are proposed for use in survey traps. Chlorpyrifos is registered for use on cotton pests and may be used in traps for mass trapping.

In most program areas, boll weevil populations would be eradicated in an average of 2½ years, with eradication confirmed by an additional season of light density trapping. An estimated 20 years would be required to completely eradicate the boll weevil in the remaining infested States in the Cotton Belt. Full Federal participation in an eradication program is expected to involve 30 percent Federal funding of all program costs. Program cooperators would determine the integrated control strategy for infested fields and how to maintain and monitor buffer zones. Under this alternative, APHIS would participate in the selection and acquisition of insecticides, supervision of any treatment required for boll weevil control, and environmental monitoring. Following eradication, APHIS intends to oversee post-eradication activities.

***Limited Federal Involvement.*** Under this eradication alternative, APHIS would participate in a cooperative program to eliminate the boll weevil from cotton-producing regions in the United States. The goal of this program would be considered accomplished when boll weevil populations are reduced to undetectable levels across the Cotton Belt. APHIS would support regional efforts to maintain buffer zones between eradicated areas and infested regions and would encourage the use of cultural control practices to protect beneficial insects and reduce the need for chemical treatment.

Under this alternative, APHIS participation would be limited to field mapping and systematic pheromone trapping to detect and delimit boll weevil pest populations, development of recommendations for

integrated control programs, supervision of post-eradication surveillance programs, and environmental monitoring.

Control activities would result in an incremental reduction in treated acreage over time. Although all cotton acreage in each geographic increment would be included in the program, only infested fields would receive treatment. The program would move sequentially from one increment to the next. The beltwide eradication effort would be expected to last about 20 years.

Limited Federal participation in an eradication program could involve 30 percent Federal funding (applied to all nonchemical program costs). Under this eradication alternative, State cooperators and their growers would make the final decision regarding control methodology, and APHIS would neither acquire nor supervise the application of pesticides.

### Alternative 3—Beltwide Suppression Program

The beltwide suppression program would use cultural and chemical control methods as described in the EIS. Mechanical and sterile insect control methods would not be used in a beltwide suppression program because they have limited effectiveness in suppressing dense populations of boll weevils. Two levels of Federal involvement are analyzed.

***Full Federal Involvement.*** Under this suppression alternative, the cooperative program would reduce and maintain boll weevil populations below economically damaging levels. To achieve this primary goal, APHIS would conduct coordinated suppression programs in conjunction with cooperating States, growers, and Federal agencies.

All of the cotton acreage in the Cotton Belt would be included eventually in the suppression effort, although only infested acreage would be treated in an effort to prevent further economic damage. The economic threshold does not represent the pest population level that results in some damage, but rather some higher level which, if left untreated, would result in economically significant cotton boll loss.

The selection of particular methods for use in the suppression program would vary across the Cotton Belt, depending on variations in boll weevil biology, availability of overwintering sites, weather patterns, and crop production requirements. This suppression program encourages the use of cultural control methods and attempts to conserve beneficial insect populations by proper timing and limited use of chemical controls. The cooperative program's integrated control approach would include the following program components: field mapping and systematic pheromone trapping to detect and delimit boll weevil pest populations, mandatory participation by cotton producers as determined by State legislation and grower referendum, judicious use of available control measures in response to existing pest conditions and

environmental concerns, and limited chemical control application to the infested acreage.

In a suppression program, the seasonal frequency of insecticide applications would normally be less in the first 2 years than for an eradication program, although much of that acreage would require repeated applications each growing season for an indefinite period. There would be no projected end to APHIS involvement in the control program. APHIS would assume a reasonable portion of the control costs. Program cooperators would determine the integrated control strategy used in the program. APHIS would also participate in the selection and acquisition of insecticides and would supervise any treatment required for boll weevil control.

***Limited Federal Involvement.*** Under this suppression alternative, the cooperative program would seek to reduce and maintain boll weevil populations below levels that would result in significant economic crop loss. To achieve this primary goal, APHIS would participate in coordinated suppression programs in conjunction with cooperating States, growers, and other Federal agencies to demonstrate the effectiveness of the suppression technology. All elements of this alternative are identical to the alternative described above, with the exception that APHIS involvement would be limited to demonstrating the effectiveness of the technology, which would generally require 3 years in each demonstration area.

## Operational Procedures and Mitigation Measures

A number of measures to increase the safety and reduce the potential impacts of the cooperative control program have been incorporated as operational procedures and mitigation measures for the alternatives being considered. The operational procedures would be a required part of control activities funded by APHIS, while the mitigation measures could also be implemented at a programmatic level. At the site-specific level, additional protective measures may be developed as a result of further analysis. The operational procedures are presented in table 2-1 and recommended mitigation measures are presented in table 2-2 in chapter 2. APHIS will stipulate applicable operational procedures and mitigation measures in cooperative agreements and applicator contracts when programs are funded or contracts are awarded. These agreements would identify the party (for example, APHIS, Federal or State land managers, or contractors) responsible for ensuring compliance with these critical safeguards.

## Feasibility of Eradication and Limitations of the Analysis

The feasibility of the boll weevil eradication program has been questioned by many groups for both scientific and socioeconomic reasons. One main area of disagreement is in the definition of eradication and the philosophical ideologies that the definition can represent.

There is always risk associated with attempts to control or eradicate pests. Moreover, control activities cannot be guaranteed to produce the desired results. Failure to eradicate the boll weevil could result in reinfestation and loss of benefits in currently eradicated areas and

increased insecticide use. Success in eradicating the boll weevil, however, would result in appreciable economic and environmental benefits well into the foreseeable future.

## The Affected Environment

The National Boll Weevil Cooperative Control Program will potentially affect the cotton-producing areas and adjacent land in the 17 States of the Cotton Belt. The discussion of the affected environment in this EIS is organized by geographically based program areas: the Southeast, the South Central, and the Southwest program areas. The Southeast program area is further subdivided into coastal and delta subareas. These areas represent distinct cotton-growing regions that differ in agronomic practices, cotton variety, and surrounding nonagricultural environment.

As illustrated in figure 3-1 (in chapter 3), the Southeast program area includes the coastal States of Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia, and the delta States of Arkansas, Louisiana, Mississippi, Missouri, and Tennessee. The South Central program area includes Kansas, Oklahoma, and Texas. The Southwest program area includes Arizona, California, and New Mexico. The geographically based program areas are not identical to APHIS, Plant Protection and Quarantine (PPQ) administrative regions, although PPQ is divided into three somewhat similar regions.

Physical and social characteristics of the affected area are described in chapter 3 of the EIS. The Southeast program area is generally composed of richer soils, greater variety in relief, and higher rainfall than the other two program areas. Cotton fields tend to be smaller, in a heterogeneous mix of other agricultural fields and nonagricultural land uses. Cotton fields are occasionally close to rural homes and vegetable gardens; many are located close to rivers and streams. The South Central program area is composed generally of high and rolling plains, with larger fields often found in large contiguous blocks. Rainfall in the South Central program area is less than in the Southeast; consequently, irrigation is often used to supplement rainfall for cotton production. Homes are generally distant from cotton fields.

The Southwest program area is composed of low relief agricultural areas. The arid climate leads to heavy reliance on irrigation for producing cotton. Homes are generally distant from cotton fields. Cotton fields in this area are typically large, although in a more heterogeneous mix with other agricultural fields than in the South Central program area.

## Costs

Total estimated APHIS costs range from $0 for the no action alternative to approximately $173 million for the eradication alternative with full Federal involvement. The suppression program with full Federal involvement would be the most expensive, because it would continue indefinitely. Although total costs were not estimated, costs for the first 30 years would be $1,616 million. Limited Federal involvement in an eradication program would cost about $103 million, and limited

involvement in a suppression program would be $275 million. Details on estimated costs can be found in chapter 4.

Regional costs of boll weevil control vary considerably throughout the Cotton Belt and depend on factors that cannot be predicted (for example, weather and degree of infestation). The range of variation in cost components is noted in chapter 4.

## Environmental and Socioeconomic Effects

Chapter 4 of this EIS examines the range of effects that could result from the use of the control methods and from the implementation of program alternatives selected for analysis. Detailed effects of chemical controls are examined. The use of malathion, azinphos-methyl, diflubenzuron, and methyl parathion is examined for possible foliar treatments. Chlorpyrifos and propoxur use in insect traps is also examined. Because xylene is an inert ingredient in the microencapsulated formulation of methyl parathion, potential effects of xylene use are also addressed.

Risks to nontarget species and humans associated with insecticide use are analyzed under typical routine and typical extreme (worst case) operating conditions and under accidental scenarios. Example accidental scenarios are the jettisoning of an 80-gallon load of insecticide into a reservoir and, in the case of humans, the spraying of an adult at the specified application rate. Conservative assumptions are used throughout the risk analysis in estimating the effects of the alternative control methods on humans and nontarget species so that no potential impacts that might occur will be overlooked or underestimated. Chapter 4 examines the effects of control methods, as well as program alternatives. This summary, however, includes only a discussion of the potential impacts of program alternatives.

### Summary of Impacts on Soil and Vegetation by Alternative

#### Alternative 1—No Action

This alternative presents an unknown impact on soils and vegetation because it is not known what control measures growers may use in the future. Fewer growers currently use cultural controls than would be expected under a cooperative control program; therefore, impacts on soil and nontarget vegetation are expected to be low except on a site-specific basis. Chemical control measures are expected to be used extensively in the absence of Federal program support. If a more persistent or toxic insecticide is chosen by the grower, this alternative could cause relatively higher toxic loadings of insecticides in soil in the treated areas. Extensive drift problems affecting adjacent food crops and the contamination of nearby water supplies may also occur in the absence of mitigation measures and operating procedures. A corollary problem could be a continual impact on insect pollinators, which would decrease plant reproduction in species dependent on insect pollination.

### Alternative 2—Beltwide Eradication Program

Under both full and limited Federal involvement, this alternative is not expected to significantly affect soil and nontarget vegetation. Nonchemical control methods are expected to be used more extensively than in the no action alternative; therefore, there could be additional site-specific impacts, such as an increased erosion potential or migration of cotton insect pests to adjacent fields after post-harvest stalk destruction. Chemical control methods are expected to be used over limited periods of time with care taken as to their selection and application schedule. All four chemicals proposed for foliar application are rapidly degraded and strongly adsorb to soil and organic matter; thus they are not expected to have significant effects on soils and nontarget vegetation.

### Alternative 3—Beltwide Suppression Program

Under both full and limited Federal involvement, this alternative is not expected to significantly affect soil and nontarget vegetation. Nonchemical control methods are expected to be used more extensively than in the no action alternative; therefore, there could be additional site-specific impacts, such as the increased potential for erosion after post-harvest stalk destruction. Because chemical control methods are expected to be used over a long period of time, it is possible that multiyear treatments could cause greater insecticide loading in soils and more long-term insect pollination problems than in the eradication alternative.

## Summary of Impacts on Nontarget Species by Alternative

### Alternative 1—No Action

This alternative is expected to produce little impact on nontarget species from nonchemical control methods because growers currently do not make extensive use of nonchemical control methods. However, most growers use chemical controls and select from a list of materials of varying toxicity. Therefore, it is likely that chemicals will be used that are more toxic than those analyzed for the cooperative control program described in this document.

### Alternative 2—Beltwide Eradication Program

Under both full and limited Federal involvement, more extensive use of nonchemical control methods is expected during this alternative than in the no action alternative. These nonchemical methods should have beneficial impacts in reducing insecticide use, especially in later program years. Impacts from the use of chemical control methods would depend on the chemicals selected. Malathion is not expected to impact nontarget terrestrial organisms except for honey bees and other beneficial insects that are directly sprayed. The use of azinphos-methyl and methyl parathion in the eradication program could adversely affect a number of nontarget terrestrial species including birds, mammals, reptiles, amphibians, and insects within or near the treatment areas.

No risks of adverse effects to terrestrial wildlife are predicted to result from the use of diflubenzuron.

For small ponds located 25 feet or more from treatment areas, malathion and azinphos-methyl may pose significant risks to fish. Azinphos-methyl, malathion, and methyl parathion could also adversely affect aquatic invertebrates in these ponds. Diflubenzuron does not seem to pose any significant risk to aquatic organisms in these offsite ponds.

In ponds that are located in a cotton field and that are accidently sprayed directly, there could be risks to aquatic invertebrates from any of the insecticides and risks to fish from malathion and azinphos-methyl.

In small streams located adjacent to cotton fields, malathion and azinphos-methyl may present potentially significant risks to fish and aquatic invertebrates. Analysis of diflubenzuron and methyl parathion indicate risk only to aquatic invertebrates in small streams.

Under worst case assumptions, azinphos-methyl and malathion could pose significant risks to fish and aquatic invertebrates if large amounts of runoff entered rivers immediately after treatment. Analysis of diflubenzuron and methyl parathion indicated risk only to aquatic invertebrates under this worst case assumption.

Operational procedures and mitigation measures have been developed to minimize effects to nontarget species. Under the eradication program, these effects could occur only near or downstream from treated fields; on an area-wide basis, the effects would be reduced substantially after the second year of the program.

### Alternative 3—Beltwide Suppression Program

Under both full and limited Federal involvement, this alternative could produce greater impacts to nontarget organisms than those of the eradication program. Under this alternative, there would be less control over mitigation measures, and a wide variety of chemicals could be used by the growers. Also, because the suppression program could continue for an indefinite period of years, there is a potential for higher risk over the long term.

## Summary of Impacts to Water by Alternative

### Alternative 1—No Action

Under the no action alternative, growers would continue to plan and implement their own boll weevil controls with no APHIS involvement. The effects on water quality of this alternative are unknown because it is not known what control measures may be selected by individual growers. Nonchemical control methods are not used extensively by growers. Therefore, they are not expected to impact water quality

except on a site-specific basis. For example, some cultural control techniques could cause additional erosion, which might lead to increased sedimentation in surface water. Impacts from chemical control methods would depend on the chemicals selected by individual growers and their adherence to label requirements and State regulations. This alternative may present higher loadings of insecticides than either the eradication or suppression alternatives if a more persistent chemical is used, if chemicals are applied more frequently, and if seasonal treatments are applied indefinitely. In addition, the insecticides used by growers could be more mobile and have greater potential to reach groundwater and surface water.

### Alternative 2—Beltwide Eradication Program

Under both full and limited Federal involvement, control program activities are expected to result in little insecticide loss in runoff or percolating water.

Environmental fate modeling indicates little potential for the proposed chemicals to leach into groundwater. The analysis also indicates that none of the proposed insecticides would be present in rivers, except during direct accidental spraying or during unusual precipitation events.

Because of different application schedules during the season and the limited duration of the program in each increment, the eradication alternative is expected to result in slightly lower estimated environmental concentrations than the suppression alternative.

Although chemicals vary in their toxicity, the eradication program is not expected to cause a significant long-term impact on water quality. Operational procedures and mitigation measures can safeguard sensitive areas and species.

### Alternative 3—Beltwide Suppression Program

As discussed above, under both levels of full and limited Federal involvement, a few more impacts are expected from the suppression alternative than the eradication program, because of an increased emphasis on diapause treatments and the indefinite number of years in the program. However, the suppression alternative is not expected to cause significant long-term impacts on water quality, particularly if operational procedures and mitigation measures are followed. It would be difficult under limited Federal involvement, however, to ensure that such procedures were being followed.

## Summary of Impacts on Human Health by Alternative

### Alternative 1—No Action

Under the no action alternative, growers would continue to plan and implement their own boll weevil control programs with no APHIS involvement. The health effects of this alternative are not quantifiable

because of the latitude individual growers have in selecting control measures. More than 14 insecticides are currently being used to control the boll weevil and safeguards are provided only to the extent that individual growers adhere to EPA label requirements and State regulations. The health effects from exposure to insecticides under this alternative cannot be quantified. Because the growers use chemical control methods extensively, the risk analysis for chemical control methods may be used to qualitatively predict risk for the no action alternative.

For systemic and reproductive health effects, the risk analysis of boll weevil insecticides indicates that risk is predicated on the toxicity of the selected insecticide. Under the no action alternative, growers may elect to apply chemicals that are more toxic than those considered for use in the cooperative control programs.

For carcinogenic effects, the risk analysis for the suppression program can be used to estimate potential effects under the no action alternative because the no action alternative assumes constant exposure over a period of 30 years or longer. Human health risks are likely to be higher under this alternative over the lifetime of the program, because the other alternatives incorporate operational procedures and mitigation measures that go beyond what is required by law. Also, uncertainties about synergistic and cumulative effects could also contribute to a higher risk for the no action alternative.

### Alternative 2—Beltwide Eradication

Under the eradication alternative (both full and limited Federal involvement), more extensive use of nonchemical control methods is expected, especially in the later years of the program. Where these methods are used, there should be beneficial impacts from reducing insecticide use. During the initial phase, the eradication program would likely use a higher frequency of applications than the suppression program. Grower applied materials in a limited suppression program, however, may be more toxic, resulting in higher and more sustained risks. Over the long term, the risks to human health under the eradication program are less because the insecticide treatments are substantially reduced after the first few years and the duration of eradication programs is less than that of suppression programs (3½ years for each area under eradication, as opposed to an indefinite period for suppression). Thus, the eradication program would be expected to have a lifetime expected exposure that is less, with a lower risk of long-term health effects, than that expected from the suppression program.

The relative ranking of overall risk to workers and the general public is as follows (from greatest to least significant): methyl parathion, azinphos-methyl, malathion, and diflubenzuron. Risks to the public may result from the consumption of garden products or fish containing insecticide residues or as a result of accidental exposures. Ground application workers are at greatest risk for all insecticides. Chapter 4 of

the EIS presents mitigation measures to ensure all human exposures would be within levels considered safe.

The variability in application schedules across the Cotton Belt can also produce different long-term risks in some regions. However, this EIS examined the most extreme scenarios and based the risk analysis on lifetime animal studies. Therefore, the risk in regions affected by the highest boll weevil populations and late program implementation are not expected to exceed those described in this EIS.

### Alternative 3—Beltwide Suppression of the Boll Weevil

Under the suppression alternative (both full and limited Federal involvement), risks of health effects would be similar to those previously described in the eradication alternative. In the short term, risks would be slightly less because of the lower frequency of treatment. However, beltwide suppression could result in expansion by the boll weevil into its maximum geographical host range, with a resultant need to treat vastly greater acreages, thereby increasing pesticide load, exposure, and risk over what might be expected with a limited duration eradication program.

## Other Environmental Effects

In accordance with the CEQ regulations for implementing NEPA, other environmental effects are addressed in this EIS. These include cumulative environmental effects; adverse environmental effects that cannot be avoided; the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity; irreversible and irretrievable commitments of resources; possible conflicts between the proposed action and the objectives of Federal, State, and local agencies; and energy requirements.

# Chapter 1

# Purpose and Need

## Introduction

Cotton is the fourth most valuable crop in the United States after corn, soybeans, and wheat. In 1986, U.S. production of cotton fiber and cottonseed was valued at $2.7 billion. Although cotton represented only 4.6 percent of the total crop revenue in the United States in 1986, it represented 25 to 33 percent of all crop revenue in many of the cotton-producing States (USDA, 1988a). Domestic U.S. cotton cultivation began nearly 400 years ago in Jamestown, Virginia, and remains a crop of critical economic importance.

This chapter describes the problems that boll weevil infestations cause in the U.S. cotton industry and the need for Federal involvement in boll weevil control. It defines the scope of this environmental impact statement (EIS), which assesses the impacts of several alternatives for Federal cooperation in boll weevil control programs.

This chapter also describes the current U.S. cotton industry, the life cycle of the boll weevil, and the damage it does to cotton. It outlines the history of efforts to control the boll weevil and current areawide control programs and the status of previously eradicated areas. Finally, it describes the organization of the remaining portions of this EIS.

## Boll Weevil Control as a National Problem

A major cost associated with producing cotton in the United States is the cost of controlling cotton insect pests. Since the cotton boll weevil, *Anthonomus grandis* Boheman, first entered the United States in the late 1800s, it has infested more than one-half of the acres devoted to cotton production, resulting in $12 billion in economic losses (National Cotton Council of America, 1973).

In areas of the Cotton Belt where it has become established, the boll weevil is a key cotton pest. In 1987, the boll weevil was directly responsible for a reduction in cotton yield of 2.24 percent, or 325,403 bales of cotton (King et al., 1988). Economic damage from the boll weevil has been estimated to be $145.1 million annually (Suguiyama and Osteen, 1988). While improved agronomic practices and insect control technology have reduced crop losses, the chemical treatments needed to control the pest have increased cotton production costs, reduced populations of beneficial insects, increased problems associated with secondary pests, and increased insect resistance to the pesticides.

Because the boll weevil is a migratory pest, it is necessary for States to cooperate among regions to ensure the success of control programs. Although some individual growers have successfully controlled boll weevils in their fields, neighboring areas may contribute to reinfestations. The boll weevil's movement is largely dependent on wind direction and speed, but it has been known to travel up to 169 miles (Guerra, 1988); therefore, reinfestations often cross State lines.

Accordingly, the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA) provides direct supervision and leadership for boll weevil control programs in cooperation with other services within the USDA, State departments of agriculture, universities, and private individuals.

APHIS cooperative management programs are authorized by the Incipient and Emergency Control of Pests [Act] (1937), the Organic Act of the Department of Agriculture (1944), the Cooperation with State Agencies in the Administration and Enforcement of Certain Federal Laws Act (1962), and the Food Security Act of 1985. In addition, each State participating in the program has control authority that permits participation in cooperative pest management programs. Existing cooperative boll weevil control programs are described later in this chapter.

## Scope of This Environmental Impact Statement

This EIS addresses the implementation of alternative federally funded activities for boll weevil control on private cropland and federally funded detection and monitoring of boll weevil populations in the Cotton Belt of the United States. This EIS also addresses control program activities that may be conducted or managed by Federal employees within the Cotton Belt.

The Cotton Belt of the United States extends from California to Virginia and includes 10 to 15 million acres of cotton in 17 States (fig. 1-1). The area infested with boll weevils, commonly referred to as the Boll Weevil Belt, includes approximately 7 million acres of cotton in all or parts of Alabama, Arkansas, Arizona, Florida, Georgia, Louisiana, Mississippi, Missouri, Oklahoma, South Carolina, Tennessee, and Texas (fig. 1-2). APHIS is participating in cooperative boll weevil control programs in the Southwest (California and Arizona), in west Texas, and in the Southeast (Alabama, Florida, Georgia, South Carolina, North Carolina, and Virginia) (fig. 1-3). Boll weevil eradication has been successfully completed in some of these areas (fig. 1-4).

In accordance with the procedural provisions of the National Environmental Policy Act (NEPA), 42 U.S.C. 4321 *et seq.*, APHIS prepared environmental assessments (EAs) in 1988 for the Southeast Boll Weevil Eradication Program in Alabama, Florida, Georgia, and South Carolina (USDA, 1988b) (North Carolina and Virginia are now boll weevil free); for the Southwest Boll Weevil Eradication Program in Arizona and California in 1988 (USDA, 1988c) (California is now boll weevil free); for the Boll Weevil Suppression Program in Mexico in 1988 (USDA, 1988d); and for the West Texas Boll Weevil Containment Program in 1986 (USDA, 1986). As a result of these EAs, APHIS determined that these programs would not have a significant impact on the human environment.

Figure 1-1. Cotton-producing Areas of the United States

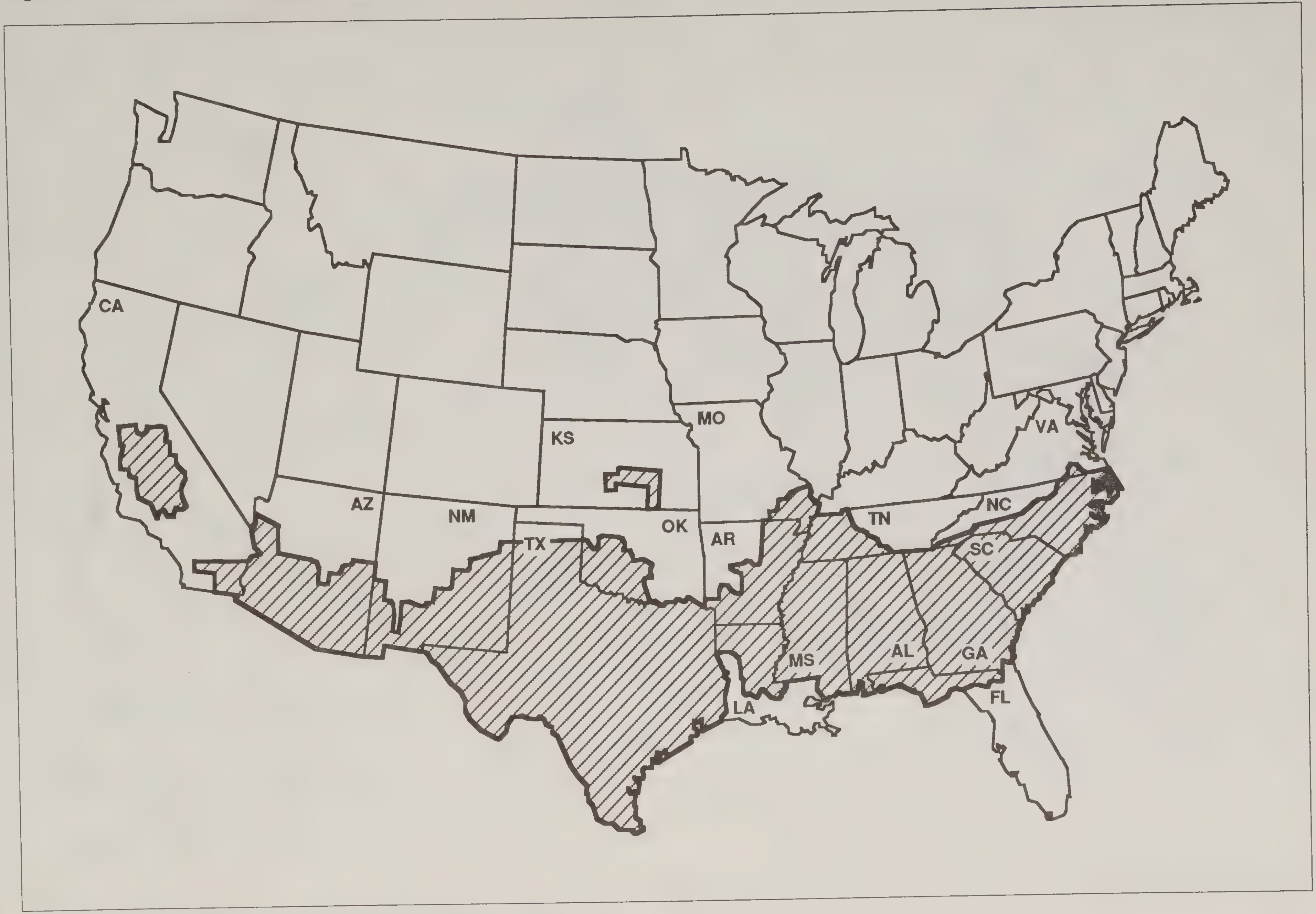


Figure 1-2. Areas Infested With the Boll Weevil (1990)

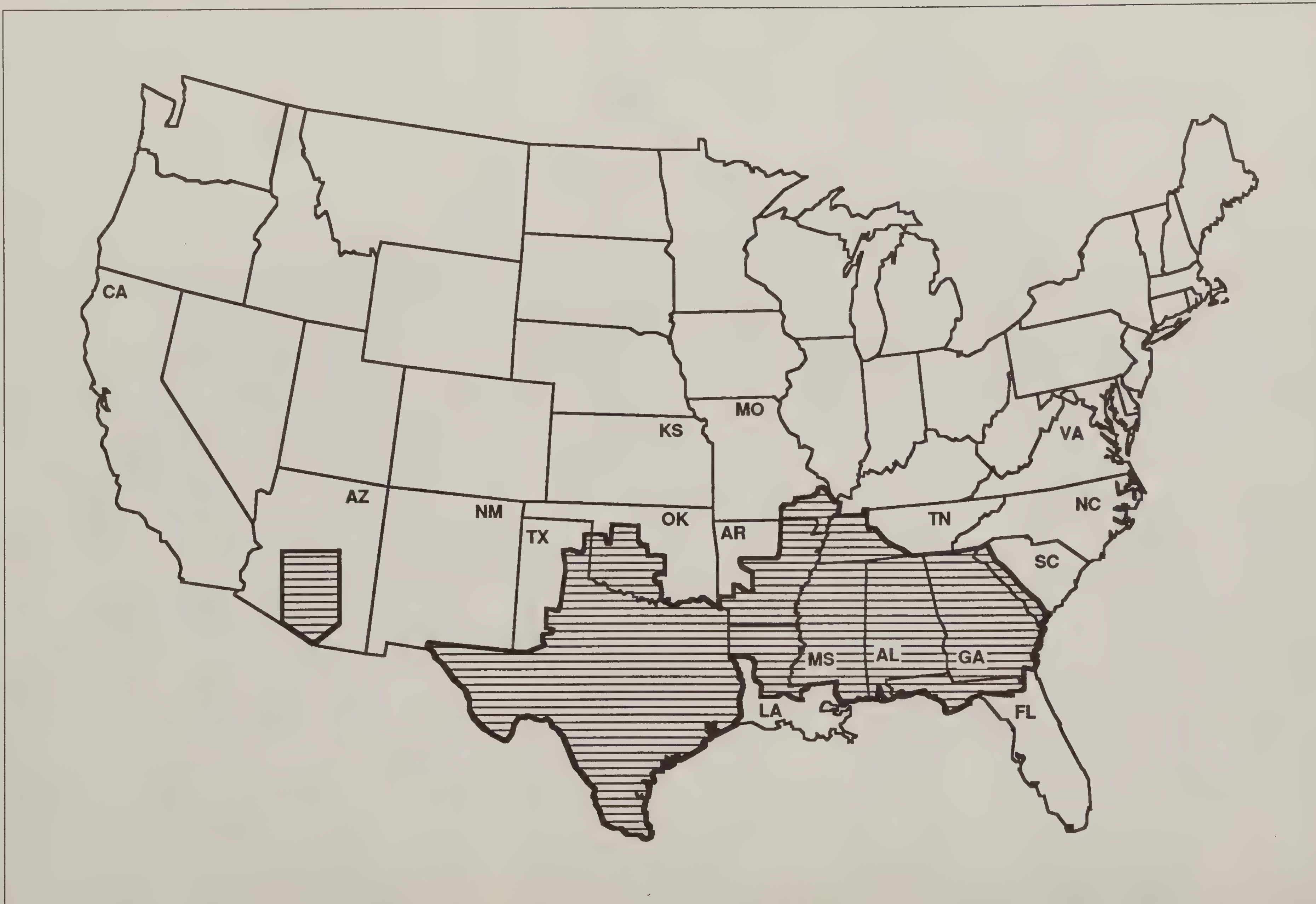


Figure 1-3. Areas Where APHIS Cooperative Control Programs Are Conducted (1990)

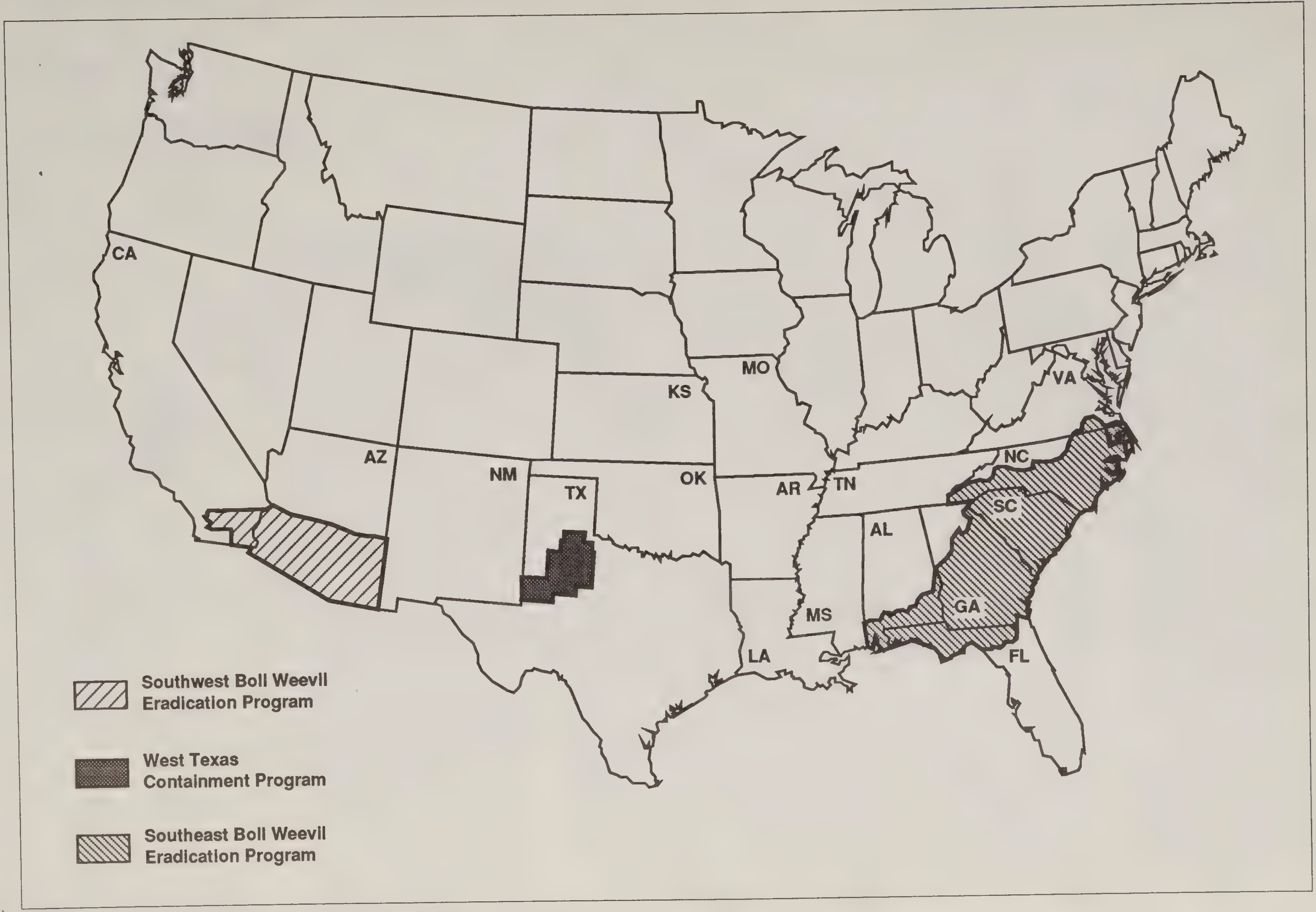
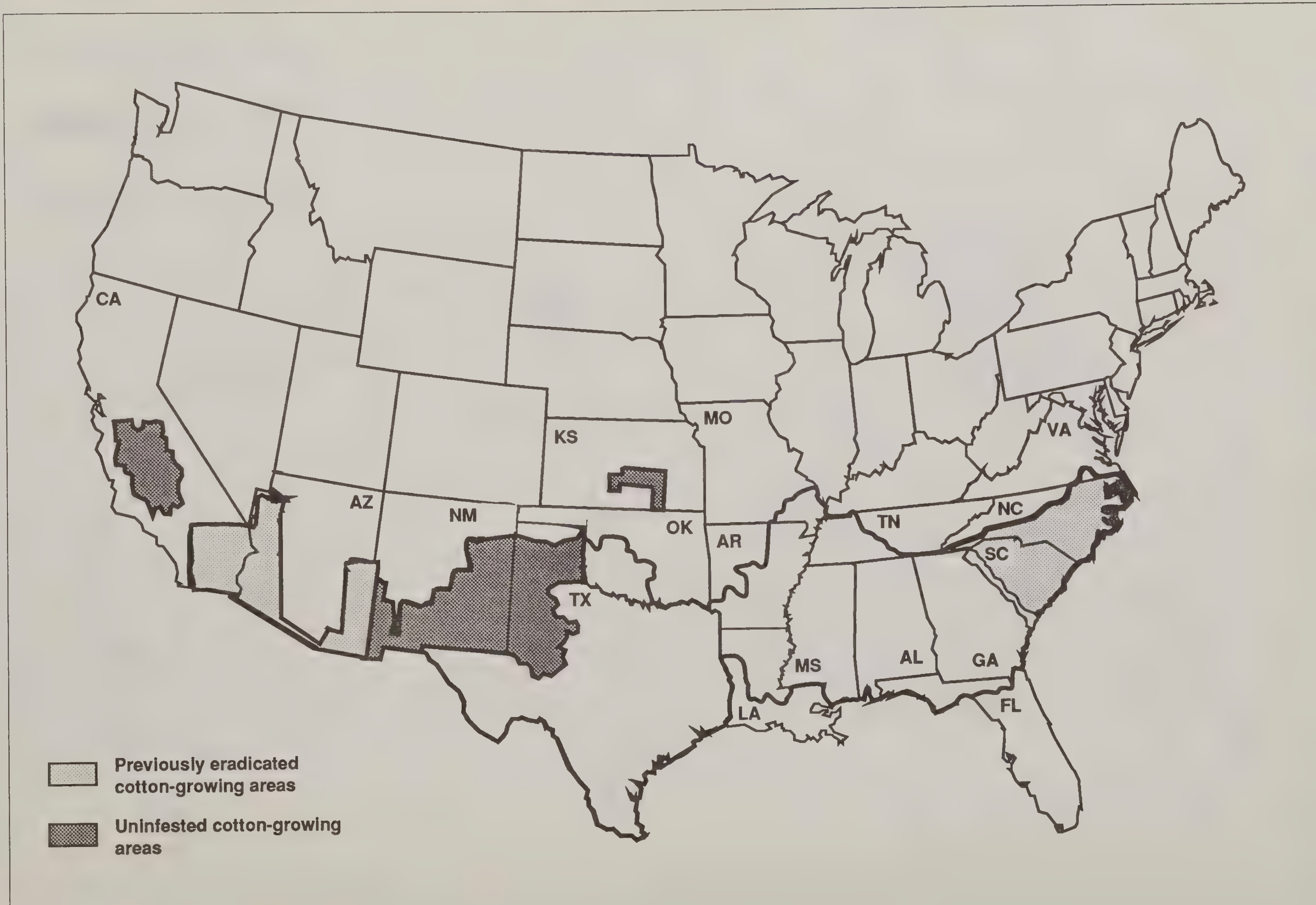


Figure 1-4. Uninfested or Previously Eradicated Cotton-Growing Areas (1990)



However, the possibility that implementation of an eradication program across the entire Cotton Belt might have a significant impact on the environment, as well as public controversy surrounding the use of azinphos-methyl treatments applied in the Boll Weevil Eradication Program in Alabama in 1987, led to a decision to prepare this programmatic EIS. This EIS is also intended to comply with a number of provisions set forth in the Stipulation of Settlement of Civil Action No. 88-H-397-N in the United States District Court for the Middle District of Alabama.

This EIS also provides basic background information needed for tiering future program-specific analyses in accordance with Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 CFR 1502.20 and 40 CFR 1508.28). That is, if any new control methods become available for implementation in the National Boll Weevil Cooperative Control Program, this programmatic EIS could be incorporated by reference in the new analysis.

Public participation has been an integral part of the preparation of this final EIS. In accordance with 40 CFR 1501.7 and 40 CFR 1506.6, scoping comments were solicited by mail and at three public scoping meetings in Montgomery, Alabama; Lubbock, Texas; and Phoenix, Arizona. Commenters included representatives of State and local government agencies, environmental groups, representatives of growers' associations, university entomologists, and other interested individuals. The issues and concerns of the public, along with the programmatic requirements of APHIS, were key elements in the development of a range of alternatives and were used to evaluate these alternatives. The issues and concerns of the public were also used in assessing the impacts of the various alternatives, in developing mitigation measures and operational procedures, and in selecting the preferred alternative. See appendix C for a summary of public participation.

With the release of the draft EIS to the public, APHIS invited comments from all agencies and individuals interested in or affected by this draft EIS. APHIS has responded to the comments received on the draft in preparing this final EIS (40 CFR 1503). In addition to comments received on the draft EIS, APHIS wrote and made available for public comment a supplement to the draft EIS. The supplement consisted of two parts: Analysis and Protection of Endangered and Threatened Species and Implementation of the Program in Alabama. Comments received on the supplement were also used in the preparation of this final EIS.

## Need for a National Boll Weevil Cooperative Control Program

### Value of the U.S. Cotton Industry

In the nineteenth and early twentieth centuries, cotton was the major agricultural crop of the Old South. In recent years, cotton also has

become a major crop in Texas and the arid Southwestern United States because of newly implemented irrigation projects (Ebeling, 1979). While cotton has historically been produced in 20 States, much of the 10.5 million acres of cotton production in 1989 was concentrated in three States—California, Texas, and Mississippi.

U.S. cotton exports have accounted for 20 to 40 percent of the world cotton trade in recent years. Although cotton is the fourth most important crop in the United States, it is essential to the economies of the cotton-growing States and to the people employed in cotton-related industries in those States. Production in 1989 was 12.2 million bales, with an estimated farm value of $3.8 billion (USDA, 1990). Approximately 40,000 growers nationwide obtain income from cotton production. More than 3 million Americans live primarily on income from cotton; another 10 million receive income from industries related to cotton, including the production of cottonseed oil, animal feed from cottonseed byproducts, and textiles.

## Cotton Pest Species

Cotton fields are inhabited by as many as 600 species of insects, spider mites, and other arthropods, referred to collectively as the cotton arthropod complex (Phillips et al., 1980; Reynolds et al., 1982). Few of these species are economically important pests; most are beneficial organisms, such as predators and parasites, that aid in the natural suppression of potential pest populations (Ables et al., 1983; Newsom and Brazzel, 1968; Phillips et al., 1980; Reynolds et al., 1982). The cotton arthropod complex is discussed in more detail in chapter 3.

Approximately 100 arthropod species, including insects and spider mites, are known to attack the cotton crop within the United States. The cotton crop is subject to attack from the time the seeds are planted until harvest. All portions of the plant may be affected, but economically important pests damage the fruiting structures—the flower buds, blooms, and bolls—and reduce the quantity and quality of the harvested lint or seed.

Of the potential pests, approximately two dozen species are believed to cause economically significant production losses. Nearly all economic losses are caused by a few "key pests" that exist in each major cotton-producing region (Suguiyama and Osteen, 1988). Key pests are species whose populations reach proportions large enough to cause significant crop damage in most years. Of these key pests, the boll weevil, the pink bollworm, and lepidopteran genus *Heliothis* are believed to cause the most consistent and serious problems for U.S. cotton producers (Reynolds et al., 1982).

## Costs of Insect Damage to Cotton

The cost of controlling insect pests constitutes a major portion of the total cost of producing cotton in many areas of the United States. Estimates of crop loss resulting from insect damage are extremely variable (Reynolds et al., 1982), and average annual losses do not necessarily reflect the severity of loss experienced by some cotton-growing States (Suguiyama and Osteen, 1988).

Average annual losses from 1951 to 1960 were 19 percent of the potential crop, or almost one bale of cotton for every five bales harvested (Newsom and Brazzel, 1968). In more recent years, however, improved agronomic practices and pest management techniques, as well as the availability of more effective insecticides, have reduced crop loss from insect damage to 5.9 percent in 1987 (King et al., 1988). Despite this reduction in crop loss, growers must spend an average of $46.91 per acre annually to control cotton insect pests (King et al., 1988).

The boll weevil has caused an estimated $12 billion in losses to the Nation's economy since its arrival in the United States. In 1980, the boll weevil was directly responsible for yield losses on about 7 million of the 14 million acres of cotton planted (USDA, 1980), despite use of the best available control practices. Between 1981 and 1984, total economic damage—including control costs—from the boll weevil was estimated to be $145.1 million annually (Suguiyama and Osteen, 1988). In 1987, despite extensive use of many insect control methods, damage from the boll weevil resulted in losses estimated at 2.24 percent of the cotton crop (King et al., 1988). Continuing crop losses from the boll weevil and the resultant high annual control costs are major contributors to the high costs of producing cotton in the United States.

The annual, repeated use of insecticides to control the boll weevil also has a devastating effect on beneficial insects of the cotton arthropod complex. Because most insecticides available for boll weevil control are not highly selective, heavy use of chemical insecticides virtually eliminates the natural predators and parasites that would normally aid in the control of secondary or minor cotton pests. As a result, growers frequently experience outbreaks of bollworms, cabbage loopers, beet armyworms, and aphids following the early season use of pesticides to control the boll weevil. Many of these minor pest species have also developed resistance to certain insecticides, further limiting the ability of the grower to effectively control pest outbreaks.

## Biology of the Boll Weevil

The boll weevil, *Anthonomus grandis* Boheman, is a small, hard-shelled snout beetle averaging 1/4 inch in length. It has a yellowish, grayish, or brownish color and becomes nearly black with age. The boll weevil belongs to the Curculionidae, a family of insects that is strictly phytophagous (plant eating). This group has a high degree of host specificity (a trait referring to insects that can live and feed on only a limited number of plant species) and generally prefers flower buds for feeding and reproducing (Cross, 1983).

Boll weevils overwinter as adults sheltered beneath brush and forest litter and in other protected locations in and around cotton fields. Adults that survive the winter emerge from overwintering sites in the spring and begin feeding on the tips of cotton seedlings and cotton flower buds (called squares). The female boll weevil deposits eggs in the cotton squares, and, later in the season, in the cotton bolls. Eggs are deposited singly at the bottom of cavities or punctures made in the

squares and bolls. The larvae feed for 7 to 14 days and pupate. After 3 to 5 days, the adults emerge.

After mating, females in the new generation begin laying eggs in 3 to 5 days. An average of five generations occur in a single growing season, although as many as 10 generations may develop under favorable conditions.

Squares that are infested with boll weevils typically fall off the cotton plant. Bolls infested with boll weevils typically remain on the plant, but they either fail to produce cotton lint or produce an inferior quality or smaller quantity of lint.

Only about 10 percent of boll weevil populations survive the winter, with even fewer numbers surviving unusually cold winters. Dry summers also can affect boll weevil populations, reducing moisture needed in overwintering sites. In general, winter temperatures have a greater impact on boll weevil populations than other climatic variables.

### History of Boll Weevil Control

The boll weevil, a native of Mexico and Central America, became established in southern Texas between 1892 and 1894. From the point of initial establishment (near Brownsville, Texas), the weevil spread rapidly northward and eastward at a rate of 40 to 160 miles per year, crossing the Mississippi River in 1907 and reaching the northeast limit of the U.S. Cotton Belt in North Carolina and Virginia before 1922. By the 1920s, the insect had infested cotton throughout the Mississippi Delta and southeastern States. Northern and western portions of Texas were colonized by the boll weevil during a subsequent range expansion that occurred between 1953 and 1966 (Newsom and Brazzel, 1968).

Initial attempts in the early 1900s to control the pest with existing insecticides (Paris green and lead arsenate) failed, and emphasis was placed on cultural control methods, such as stalk destruction, trap crops, and manual collection of infested bolls and squares (Ridgway and Lloyd, 1983). Some States proposed establishing cotton-free zones to prevent further spread of the boll weevil into the Cotton Belt. Legislation of this type did not receive widespread support, and prohibition efforts were abandoned (Davich, 1988).

Research in the 1920s indicated that successful, inexpensive control could be achieved by dusting the cotton crop with calcium arsenate. However, some adverse side effects were soon discovered. Calcium arsenate eliminated beneficial insects that were the natural predators of other cotton pests, such as the bollworm and cotton aphid, and other insecticide applications became necessary to control these pests. Arsenate accumulation in the soil also had a phytotoxic effect on rotation crops, such as rice, oats, and legumes, and reduced their yields (Parencia, 1978). However, using calcium arsenate to control boll weevils made it possible to produce cotton economically in the Southeastern United States, and aerial dusting became the principal method of applying inorganic insecticides to cotton until the late 1940s.

In the 1940s, the development of organochlorine insecticides, including DDT, aldrin, dieldrin, endrin, and toxaphene, brought about a revolution in cotton insect control. Because these compounds were persistent, oil-soluble, contact insecticides, application by aerially applied spray became possible. Low-volume sprays almost totally replaced dust applications in the 1950s (NRC, 1981). The organochlorines proved highly effective in controlling a wide variety of cotton pests, and their persistence made them useful in controlling newly emerging populations of weevils and weevils migrating from other areas.

By the mid-1950s, however, the boll weevil was becoming resistant to organochlorine insecticides. In addition, concern was growing about the destruction of beneficial insect populations and the widespread occurrence of organochlorines in the environment. Thus, organochlorines were gradually abandoned in favor of organophosphate insecticides. However, organophosphates were not as effective or as economical as organochlorines in controlling boll weevils. Because organophosphates are less persistent than organochlorines, they had to be applied more frequently. In addition, the tobacco budworm and the bollworm developed resistance to some organophosphates and the carbamate insecticide carbaryl in many areas of Texas and Mexico in the early 1960s. Uncontrollable outbreaks of budworms and bollworms led to the destruction of the cotton industry in the Ciudad Mante/Tampico region of Mexico in the late 1960s (Knipling, 1979). This resistance also occurred later in many areas of the Southeast and the Southwest. Although the boll weevil has shown resistance to organophosphates in Central America, it has not yet developed resistance in any portion of its U.S. range.

Systemic compounds (insecticides that are translocated by the cotton plant to the site of insect contact) were also tested extensively in the mid-1950s and early 1960s. Research was directed toward the development of a seed or soil treatment that could retard the development of damaging boll weevil populations during the growing season. Boll weevil control was generally poor in field tests of these compounds, and some yield loss and bollworm buildup were also noted. Research on these compounds was subsequently abandoned.

Research into nonchemical control methods also continued during this period. Various predators and parasites were imported from Africa (Cross et al., 1969) and South America (Little and Martin, 1942), but they were unable to survive and establish biological control of the boll weevil. Other researchers attempted to develop mechanical devices to collect infested bolls and squares. These devices also failed to provide adequate control. Chemosterilant sprays, various baits, and hybrid sterility were also tested, but they failed as effective control methods.

During the past 10 years, substantial research has been devoted to the development of new insecticides to aid in the control of insecticide-resistant cotton insect pests. At this time, more than 30 insecticides and acaricides (used to control mites) are used regularly to control cotton

arthropod pests, and the Environmental Protection Agency (EPA) has conditionally approved another four for specific uses against cotton pests.

Although only about 5 percent of the total crop acreage in the United States is regularly treated with insecticides, it has been estimated that as much as half of these insecticides are applied to control cotton pests (Pimental, 1973). Forty percent of the pesticides applied to cotton are used specifically for boll weevil control (Suguiyama and Osteen, 1988). Despite the development of new insecticides, cotton insects continue to develop resistance. Some researchers believe that the routine use of insecticides to protect crops from boll weevil damage does not lead to a permanent solution to the problem and may, in fact, lead to the development of resistance to insecticides in the boll weevil and other cotton insect pests (Knipling, 1979; Metcalf, 1980; Parencia et al., 1983).

## Development of Areawide/Beltwide Boll Weevil Control Programs

### Need for a Beltwide Control Strategy

Yield losses attributed to the boll weevil, the costs of insecticide control, environmental considerations, intensification of secondary insect pest problems, and insect resistance have all resulted in an aggressive effort to develop a beltwide strategy for controlling the boll weevil in the United States (NRC, 1981).

Although most growers judiciously apply control measures to boll weevil-infested acreage, in almost all such areas, 5 to 20 percent of the infested acreage may receive inadequate or no control treatments (Knipling, 1979). This untreated acreage harbors populations capable of reinfesting neighboring areas. Models developed by Knipling (1979) demonstrate that if only 10 percent of a population remains untreated, that portion of the population can develop normally and redistribute throughout the entire area after only four generations or in less than one growing season. Also, judicious application of control measures cannot protect against reinfestation from neighboring areas the following season. Thus, growers who do treat their acreage are faced with a continuing need to reapply insecticides to control reinfestations.

In addition, the effectiveness of nonchemical control techniques is greatly diminished unless implemented on an areawide basis. For these reasons, most pest management professionals agree that successful boll weevil control programs require participation by 100 percent of the growers (Knipling, 1979; NRC, 1981; Reynolds et al., 1982).

## Beltwide Control Trials

The Pilot Boll Weevil Eradication Experiment was established in 1971 in view of the economic and environmental problems posed by the boll weevil and in recognition of the technical and operational advances in boll weevil control techniques. This cooperative effort, involving Federal and State agencies and growers' associations, was designed to determine whether it was technically and operationally feasible to eliminate the insect on an areawide basis. The eradication experiment covered all or parts of 30 counties in southern Mississippi, 5 parishes in

Louisiana, and 2 counties in Alabama. The integrated control approach included chemical treatment, releases of sterile males, mass trapping, and cultural control.

At the conclusion of the 2-year experiment, weevil populations had reached undetectable levels in all but 9.2 percent of the acreage in the eradication zone. On the basis of this experiment, a special study committee of the National Cotton Council of America concluded that it was technically and operationally feasible to eliminate the boll weevil.

The operational goal of an eradication is considered to have been met when the boll weevil population has been reduced to undetectable levels. Eradicating the boll weevil may take an extra season or two on some fields.

A special committee appointed by the President of the Entomological Society of America independently concluded that eradication (reduction of a species population to zero) had not been demonstrated in the above experiment, but that populations had been reduced to undetectable levels throughout the eradication zone. The committee urged additional refinement of the control techniques before a beltwide program was attempted (Eden et al., 1973).

Subsequent discussions among Federal and State research, extension, and regulatory officials and growers' associations led to a decision by USDA in 1977 to conduct two additional areawide boll weevil control trials, which are briefly described below.

The Optimum Pest Management (OPM) Trial in Mississippi (1978 to 1980) was designed to test the technical and operational feasibility of an areawide voluntary cotton insect suppression program and included educational services and technical assistance. The 3-year trial was conducted on 32,000 to 40,000 acres of cotton in Panola County, Mississippi. Program control methods included chemical diapause treatment, pheromone trap monitoring, and voluntary stalk destruction. (Refer to the Glossary for definitions of terms.) At the end of the trial, weevil trap catches had been reduced by 94 percent. As a result, USDA considered this suppression trial to be a biological and technical success (USDA, 1981).

The Boll Weevil Eradication (BWE) Trial (1978 to 1980) was designed to test the technical and operational feasibility of eradicating an established boll weevil population. The 3-year trial was conducted on 32,500 acres in North Carolina and Virginia. Participation was mandated by State legislation, and program control methods included in-season and diapause chemical treatment, use of pheromone traps for population monitoring, mandatory stalk destruction, and sterile insect release. Upon completion of the program, only 15 boll weevils were detected in the 32,500 acres. USDA also considered this eradication trial to be a biological and technical success (USDA, 1981). The success

of the BWE trial led to boll weevil eradication programs in the Southwest and Southeast.

### Current Boll Weevil Cooperative Control Programs

***Southwest Boll Weevil Eradication Program.*** The Southwest Boll Weevil Eradication Program, which was implemented in 1985, was designed to eradicate the boll weevil in approximately 233,000 acres of cotton in western Arizona, southern California, and Northwest Mexico (fig. 1-3). The control methods used in the program include pheromone trapping to delimit populations, judicious use of chemical treatments, and dependence on grower-implemented cultural controls, including timely stalk destruction and uniform planting. The initial eradication effort in western Arizona is completed, and the program has been expanded to include an additional 420,000 acres of cotton in central Arizona. The post-eradication activities in southern California protect approximately 1.1 million acres of uninfested cotton in the San Joaquin Valley. A cooperative program in Mexico has successfully eliminated the boll weevil from fields that adjoin U.S. production areas in California.

During the 4 years of the initial Southwestern program, control activities involved significantly less acreage each season. A net result of eradicating the boll weevil has been an elimination of the need to use insecticides to control the pest.

Eradication of the boll weevil in cotton-producing areas in southern California and western Arizona was completed in 1989.

The expanded program began in 1988 and covered 420,000 acres in central Arizona and 5,000 acres in Mexico. During the first year, more than 4.2 million boll weevils were trapped and 900,000 cumulative acres were treated. In 1991 only 56 weevils had been captured as of October and only 798 cumulative acres had been treated. Eliminating the boll weevil in Southwest cotton production areas will enable growers to manage more effectively the remaining cotton pests, such as pink bollworms and whiteflies. Eradication efforts in central Arizona are expected to be completed in 1992.

Few complaints were received from area residents about the program in the Southwest. Many people in the area are accustomed to malathion spray applications because this technique is commonly used for mosquito abatement. However, beekeepers have questioned the impact that spraying operations may have on honey production and bee survival. Scoping comments from area residents are summarized in appendix C. In addition, comments received on the draft EIS and supplement are in appendix D.

***West Texas Containment Program.*** Each year since 1964, APHIS has participated in a cooperative boll weevil containment program conducted between the High Plains and the Rolling Plains of west Texas

(fig. 1-3). Sites targeted for program treatments are infested cotton fields located within a 15-county designated control zone to the northeast and southeast of Lubbock, Texas, that pose a hazard of weevil dispersal. The control zone is located primarily in the Rolling Plains to the east of the High Plains.

The containment effort is designed to prevent the westward migration of the boll weevil into more than 3 million acres of High Plains cotton production. Currently, growers in 25 counties in Texas participate in the containment program. More than 450,000 acres of cotton are surveyed and monitored annually. In 1990, 114,265 acres in 15 counties were treated for boll weevil control.

The containment methodology uses survey methods to identify and predict treatment areas. Containment treatments consist of aerial applications of malathion at ultra-low-volume (ULV) rates to fields containing high populations of weevils within the control zone. Two to four chemical treatments are applied in the fall to reduce the number of boll weevils entering dormancy or diapause and to impede the migration of reproductive adults to overwintering sites from the control zone into the uninfested High Plains. By suppressing the boll weevil population before dormancy, the program seeks to minimize the population that emerges the following spring.

In the 27 years of the program, there have been few complaints from area residents. Most serious complaints concerned requests to delay spraying to avoid additional problems with the cotton bollworm. Other complaints from beekeepers resulted in the development of additional notification and mitigation procedures, as well as improved compliance monitoring. These procedures may include general notification through various media, written notice or telephone contact with registered beekeepers, and onsite notification where appropriate.

***Southeast Boll Weevil Eradication Program.*** The Southeast Boll Weevil Eradication Program is designed to eradicate the boll weevil from approximately 500,000 acres of cotton in the remaining area of South Carolina, Florida, Georgia, and the southern counties of Alabama (fig. 1-3). The program also maintains previously eradicated areas in Virginia, North Carolina, and South Carolina as a part of the post-eradication plan. A flexible buffer zone on the western edge of the program area is also maintained to prevent boll weevil populations from moving back into the eradication zone.

In 1991, more than 580,000 acres in 108 counties in Florida, Georgia, and southern Alabama were included in the expanded eradication program. Nearly all the counties in Florida, Georgia, and southern Alabama that are not in the buffer zone are 95-percent boll weevil free. Eradication treatments are continuing on the remaining 5 percent of fields. The Alabama counties bordering infested acres in central Alabama and Mississippi are considered part of the buffer zone. In addition, more than 60,000 acres from the previous buffer zone in South

Carolina are in the final stage of eradication. Nearly 625,000 weevil-free acres in Virginia, North Carolina, and South Carolina are also regularly monitored to detect boll weevil movement back into previously eradicated areas.

The control methods used in the program include pheromone trapping to delimit populations, judicious use of chemical treatments (azinphos-methyl in 1987 and malathion in 1988 to 1991), and grower-implemented cultural controls, including timely stalk destruction. In past eradication efforts in Virginia, North Carolina, and South Carolina, control activities have involved significantly less acreage each season. A net result of the eradication effort has been a progressive reduction in the amount of pesticides required for boll weevil control. In areas where the boll weevil has been eradicated, beneficial insects can, and have been, carefully managed to control secondary pests. The amount of pesticides applied to control these pests has been dramatically reduced. The economic and environmental benefits associated with this change will continue indefinitely.

The 4-year cooperative eradication effort is nearly completed in Florida, Georgia, and southern Alabama.

Numerous complaints from area residents were received during azinphos-methyl spraying operations in 1987. Complaints included reports of fish kills in farm ponds, loss of livestock, pesticide contamination of gardens, and beehive loss. All complaints were investigated by program personnel and State agencies. A summary of the types of complaints and the programs' response is provided in appendix I.

The potential for fish, livestock, and beehive loss, as well as the potential for contamination of gardens and lawns from pesticide drift, is discussed in chapter 4.

## Status of Previously Eradicated Areas

Cotton producers in the eradicated areas of the Cotton Belt have been able to reduce their total pesticide use by 50 to 90 percent. The corresponding reduction in production costs has allowed these growers to produce cotton more profitably and will ultimately make their cotton more competitive in U.S. and world markets. Cotton acreage has increased in these eradicated areas, which has had direct and indirect benefits in many rural communities.

In areas where the boll weevil has been eradicated, beneficial insects can and have been carefully managed to control secondary pests. Because the program has eliminated the traditional need for early-season boll weevil control, beneficial insects have been much more effective in controlling secondary pests. The program also has demonstrated effective ways of using biological controls on secondary pests following boll weevil eradication. Thus, the amount of chemical pesticides applied to control secondary pests has been dramatically reduced.

### Virginia

In the late 1970s only a few hundred acres of cotton were grown in Virginia; in 1991 about 17,000 acres were planted, and at least one new cotton gin has been constructed. It has been more than 5 years since the last boll weevil was trapped in Virginia, and there is no indication that another pest has filled the boll weevil's niche (USDA, 1990). Total insecticide applications for growers in this area have been reduced from 10 to 12 per year to an average of 2 applications per year (Planer, 1988).

### North and South Carolina

In 1977 when the program began in North Carolina, approximately 40,000 acres of cotton were grown in the State. In 1990 more than 200,000 acres were planted in North Carolina. Projected acreage for 1991 is more than 450,000. Since 1980 more than 25 major cotton gins have been constructed or renovated in North Carolina. This expanded ginning capacity provides employment for 100 full-time and 200 seasonal employees (according to a personal communication with W. Dickerson, 1991). It is likely that the effect on the farm implements and supply industries has been comparable.

The program expanded into South Carolina in 1983 when the State produced about 100,000 acres of cotton. By 1990 the cotton acreage in South Carolina increased to about 150,000 acres, with more than 200,000 acres expected in 1991. Growers in these two States now apply an average of only three to six insecticide applications (Planer, 1988), predominantly for *Heliothis* spp. (USDA, 1990). In the North Carolina program area, insecticide applications for controlling all remaining cotton pests decreased 88 percent compared to pre-program applications (Lloyd, 1986; as cited in Matthews, 1989). These environmental and economic benefits will continue indefinitely.

### California, Arizona, and Mexico

The Southwest Eradication Program was begun in 1985 and, like the Southeast Eradication Program, has been successful. The Southwest program differs from the Southeast program in several ways. It was found that boll weevils in the Southwest program area emerge from localized areas close to suitable overwintering sites, primarily near rivers, irrigation canals, and residential areas near cotton fields. In addition, compared to the Southeast, weevil populations were relatively low in the spring. Therefore, areawide diapause treatments were not used the first fall of the program as they had been in the southeastern States. In subsequent years selective diapause treatments were used to complete eradication (Planer, 1989). The original Southwest program area covered 233,000 acres in southern California, western Arizona, and Northwest Mexico. In 1989 only 752 weevils were trapped in the entire area. In 1990, not a single boll weevil was trapped in the program area (Foster, 1990).

The success of boll weevil eradication in these widely varying environments located at opposite ends of the Cotton Belt suggests success for the eradication program in the remainder of the Cotton Belt.

## Monitoring

In accordance with its continuing responsibilities under NEPA to assess the environmental impacts of its programs, APHIS monitors many different environmental components in all treatment areas as part of its boll weevil control program. APHIS has developed environmental monitoring plans for each major program area. Monitoring plans consist of guidelines designed to assess environmental impacts of the treatment program. The three categories of sample collections are routine samples, sensitive site samples, and complaint or urgent request samples. In general, the plans call for the collection of various physical and environmental components from sites selected by program officials, based on criteria established in each plan. Samples consist of flowing or impounded water, sediment, fish, vegetation, and soils in or adjacent to fields designated for treatment. Sensitive sampling locations include fields near or adjacent to residences, schools, parks, or recreation areas; endangered or threatened species habitat; and sites that may be subject to runoff.

## Organization of This EIS

This EIS is organized to comply with the format specified in Council on Environmental Quality regulations (40 CFR 1502.10). This chapter has described the underlying need for and purpose of APHIS cooperation in a National Boll Weevil Cooperative Control Program. Chapter 2 describes the range of alternatives that were developed in response to the scoping process and the process by which some of the alternatives were eliminated from detailed study. Chapter 2 also describes the various control methods that were incorporated into the alternatives and contains a summary of the program impacts described more fully in chapter 4. Operational procedures and mitigation measures are included for all alternatives. Chapter 3 describes the environment that may be affected by the implementation of any of the alternatives. Chapter 4 describes, evaluates, and compares the alternative control strategies in terms of their impacts on human health, the environment, and social and economic conditions. Chapter 5 describes Federal, State, and local environmental regulations and consultation requirements associated with the control activities and outlines the process of coordination with State and local agencies. Chapter 6 contains a list of preparers, and chapter 7 contains the distribution list for the draft EIS, supplement, and final EIS. References cited and the glossary follow chapter 7.

Appendices follow the glossary. Appendix A contains a list of cotton-producing counties in the United States. Appendix B contains the human health and nontarget species risk assessment, including the hazard, exposure, and risk analyses. Appendix C is a summary of comments received through the public involvement in the NEPA process. Appendix D contains the comments received on the draft EIS and supplement. Appendix E contains tables showing annual acreage and costs of the various boll weevil control programs and methods. Appendix F contains a list of the scientific names of nontarget species. Appendix G is a list of the State-designated endangered and threatened species. Appendix H is the Analysis and Protection of Endangered and

Threatened Species supplement, and appendix I is the Implementation of the Program in Alabama supplement.

# Chapter 2

# Alternative Programs for Boll Weevil Control

## Introduction

This chapter describes alternative boll weevil control programs, the methods those programs would use to suppress or eradicate the boll weevil in the Cotton Belt, and the process used to develop the program alternatives. Control methods that could be used in boll weevil control programs are described in detail. These methods include cultural control, mechanical control, the release of sterile insects, and chemical control. A summary of the potential impacts of each of these control methods follows. Biological control methods, which were considered but eliminated from detailed study, are described.

This chapter provides a detailed description and analysis of several program alternatives. These include: no action, eradication with full Federal involvement, eradication with limited Federal involvement, suppression with full Federal involvement, and suppression with limited Federal involvement. Three alternatives that were considered but eliminated from detailed study, nonchemical, integrated pest management (IPM), and direct subsidies to growers are also described.

Finally, the chapter identifies the preferred alternative, discusses the criteria that were used in the selection of that alternative, and lists operational procedures that would be required under the preferred alternative and mitigation measures that would be used to minimize potential human health and environmental effects.

## Development of the Program Alternatives

### Scoping

During the scoping process for this environmental impact statement (EIS), the Animal and Plant Health Inspection Service (APHIS) held three public scoping meetings and requested written comments on the program (53 FR 27735, July 22, 1988). The scoping meetings were publicized through radio, television, and newspaper announcements. In addition, the U.S. Department of Agriculture's (USDA's) Southeast Boll Weevil Eradication Program sent 5,700 copies of a newsletter notification to cotton growers, county agents, Agricultural Stabilization and Conservation Service personnel, and other interested persons.

Oral and written comments were received from more than 30 individuals and organizations representing a broad range of interests. APHIS considered all of these comments in determining the scope of issues and alternatives to be addressed in the EIS. Appendix C contains a summary of the comments received during the scoping process.

Most commenters expressed support for a beltwide eradication effort, citing the inability of individual growers to eliminate the pest, the continual need for pesticides to protect the crop, and the increased potential for insects to develop resistance to sustained commercial pesticide applications for boll weevil control. Other commenters expressed doubt that any pest population could be totally eliminated, and they urged APHIS to consider implementing a beltwide suppression program.

In general, program alternatives recommended by commenters fell into the following three categories:

1. Current grower practices (no APHIS action)

2. Beltwide eradication

3. Beltwide suppression

Many commenters had specific suggestions and recommendations regarding the control methods to be used in any eradication or suppression program. Most expressed support for the cooperative program's current integrated control approach, as implemented in the boll weevil eradication program in the Southeast and Southwest. Other participants commented on the need to develop a control strategy with limited or no reliance on pesticides.

Control methods suggested for consideration in the analysis included chemical control, sterile insect release, biological control by predators and parasites, cultural control, and mechanical control by mass trapping.

Commenters also expressed considerable interest in specific issues that they believed needed to be addressed in the EIS. These topics included long- and short-term impacts of pesticide applications, potential economic benefits from boll weevil control, and potential impacts of control programs on beneficial insects. These topics and other scoping comments are summarized in appendix C.

## Program Alternatives and Control Methods Eliminated From Detailed Study

In addition to examining methods and programs suggested in the scoping process, APHIS conducted an extensive search of the scientific literature to identify all available methods for boll weevil control. Control methods and program alternatives were evaluated in terms of efficacy, commercial availability, operational feasibility, beltwide applicability, and cost. Control methods or program alternatives that failed to meet these criteria were eliminated from detailed study. The control methods eliminated include biological control with predators and parasites and the use of resistant plant varieties. The nonchemical alternative, IPM, and direct subsidy to growers also were eliminated from detailed study. The rationale for eliminating these control methods and alternatives from further consideration is addressed in later sections of this chapter.

## Control Methods

### Control Methods Selected for Detailed Study

The following sections describe methods for controlling boll weevil populations and the technical characteristics of each method. Methods that could be included in an eradication or suppression program, as well as methods that are not practical or feasible, are identified. Control methods addressed in these sections include cultural control, mechanical control, sterile insect technique, and chemical control. Combinations of these methods determine the actions proposed in each of the program alternatives described later in this chapter.

#### Cultural Control

Cultural control involves modifying the crop environment to make it less favorable for pest reproduction and survival (DeBach, 1974). Cultural methods currently used in boll weevil control include:

- "Short-season" techniques of cotton production, which involve growing short-season cotton varieties and manipulating planting and harvesting dates
- Postharvest stalk destruction, with prohibitions against cultivation of perennial cotton
- Limited use of trap cropping
- Crop rotation
- Voluntary limit on cotton production on sites adjacent to sensitive areas or difficult-to-treat fields

***Short-Season Techniques.*** Short-season techniques of cotton production often depend on the use of short-season cotton varieties. These varieties begin fruiting more quickly after planting and mature their fruit more rapidly than older, full-season varieties. Field studies have shown that acceptable cotton yields result when boll weevil numbers are suppressed below damaging levels for at least the first 30 days during the active blooming period (Frisbie et al., 1983). Cotton bolls more than 10 days old are less attractive to the boll weevil and are more likely to escape damage (Frisbie et al., 1983). By developing bolls more rapidly than other cotton varieties, the short-season varieties thus increase the likelihood that an acceptable crop can be produced at an early stage in the growing season, before boll weevils increase to levels capable of causing significant yield reductions.

The short-season technique is used most commonly in the Texas Coastal Bend and the lower Rio Grande Valley, where extremely damaging boll weevil and bollworm infestations occur. In these areas, short-season varieties increase the potential for an economically viable crop (Namken et al., 1983). In many areas with prolonged growing

seasons, short-season varieties are also used as replacement crops if the initial crop is destroyed by weather early in the season. However, the use of short-season varieties under these circumstances actually prolongs the availability of host material and exacerbates boll weevil infestations.

A number of short-season varieties are commercially available, but performance varies among the different regions of the Cotton Belt. A large number of varieties were developed in Texas and are adapted primarily to conditions in the Southwest. They perform poorly in the southeastern and Delta States (Namken et al., 1983). Although many short-season varieties currently produce acceptable yields, in many cases the lint quality is poor. Many growers in the Southwest have experienced problems with buyers refusing to offer advance contracts for short-season-variety lint. Until short-season varieties with improved lint quality and wider geographic adaptability are developed, the value of short-season varieties as a method of boll weevil control in areawide programs will be limited.

***Stalk Destruction.*** Mandatory postharvest destruction of stalks and prohibitions against the cultivation of perennial cotton are designed to provide at least a 60-day period between growing seasons in which no cotton is available for boll weevil feeding or reproduction. The combination of rapid crop maturation, prompt harvesting, and the destruction of cotton stalks following harvest interferes with preparations for diapause by adult boll weevils, thus reducing overwintering populations (Frisbie et al., 1983).

In the southern portion of the Cotton Belt, postharvest stalk destruction artificially terminates new growth of the plant that might occur because of prolonged growing seasons. In the northern area of the Cotton Belt, early frosts end plant growth, but stalk destruction still provides an additional measure of control.

The effectiveness of postharvest stalk destruction also depends on the method used to destroy the stalks (mowing, discing, or shredding) and on postharvest weather conditions. Because cotton is a perennial plant, warm weather after harvest can cause regrowth at the base of mowed stalks throughout some parts of the Cotton Belt. Regrowth may even occur on shredded plants or in fields that have been disced.

Even where there are extensive brush and wooded areas normally used for overwintering sites, significant numbers of boll weevils will overwinter in unopened cotton bolls. In all areas, destruction of the bolls is important in reducing the populations that will emerge in the spring.

Historically, postharvest stalk destruction has proven to be the most effective nonchemical control method for reducing overwintering populations of boll weevils. APHIS strongly encourages this method, although enforcement of this practice is the responsibility of State

agencies. Some States currently participating in cooperative eradication programs do not mandate postharvest stalk destruction, especially following eradication.

***Trap Cropping.*** Trap cropping is the early planting of strips or small blocks of cotton that are particularly attractive to emerging adult boll weevils; it concentrates adults in small areas where they can be killed by localized insecticide treatments. In a cultivation system based on uniform planting of a short-season cotton variety, for example, the trap crop is typically a strip or block that is planted 2 to 3 weeks earlier than the remainder of the crop. As the remainder of the crop develops, the trap crop has already matured and has become attractive to the weevil. During the period when adult weevils are emerging from winter diapause and searching for feeding and reproduction sites, they concentrate in the trap crop, which provides the only source of host material available at that time. In other cultivation systems, trap areas may contain a cotton variety that is highly attractive to weevils, while the main crop is a different variety known to be less attractive or more resistant to weevil attack.

With trap crops, the concentrated weevil populations must be destroyed with insecticides. Historically, systemic insecticides (those that are taken up by the roots of the plant and translocated to vegetative structures) were used to kill the trapped weevils. The insecticides were mixed with the soil during tilling operations—a process called in-furrow or sidedress treatment. Most growers used the systemic insecticide aldicarb. This treatment, however, also eliminated the natural enemies of *Heliothis* sp., which caused severe crop damage (Timmons et al., 1973). Ground application of organophosphate (a phosphorus-containing organic pesticide that acts by inhibiting cholinesterase) insecticides is now more commonly used to kill the concentrated weevils.

The use of trap crops has not gained widespread acceptance by growers in the Cotton Belt. As a result, the trap crop method is unlikely to be an important control technique in an areawide program. In northern areas, cool spring weather makes early planting of the trap crop infeasible. In warmer areas of the Cotton Belt, growers have heavy demands on their time during the period when trap crops should be planted (Lloyd et al., 1983). Although the use of trap crops has not resulted in a consistently high level of suppression (Rummel et al., 1976), the technique may be useful to individual growers who want to limit insecticide treatments to a small area.

***Crop Rotation.*** Annual crop rotation is a widely used agricultural technique that may be helpful in maintaining soil fertility and in preventing uninterrupted increases in pest populations that can occur in fields in which the same crop is grown repeatedly. Because the boll weevil is a highly specialized insect that requires cotton plants and fruits for successful feeding and reproduction, rotating to a crop other than cotton can be an effective tool for short-term suppression of local

populations on an individual field. However, removing one field from cotton production will not eliminate the boll weevil population that previously inhabited that field. Because of the migratory nature of the boll weevil, that population may simply move to an adjacent or nearby cotton field.

Grower acceptance of crop rotation is also an important factor to consider when evaluating crop rotation as a potential method of controlling boll weevils. Cotton is a relatively valuable crop, and few crops can compete with its profitability. Although many growers in the Southeast rotate to peanuts annually because they are an economically viable crop and the rotation improves soil fertility, in other regions, such as the Mississippi Delta, cotton is the only economically viable crop, and rotation is practiced only on extremely poor soils. Thus, because of limited grower support, crop rotation is unlikely to be an important control technique in an areawide boll weevil control program.

***Production Limitation.*** Encouraging growers to avoid planting cotton in environmentally sensitive areas, or in areas that are difficult to chemically treat with ground or aerial application equipment, helps ensure that all boll weevil outbreaks occurring in a region can be safely treated with insecticides—if such action becomes necessary. States currently participating in cooperative control programs encourage growers to avoid planting cotton in these areas because it would jeopardize the success of the program or present a hazard to public health, safety, or an environmentally sensitive resource if chemical treatment were necessary. APHIS joins the cooperating States in strongly encouraging growers to avoid planting cotton in areas difficult to treat with application equipment or in environmentally sensitive areas. This kind of cultural control can be very helpful in implementing a cooperative control program, but is infeasible to include as a required part of the program. Regulations limiting production, if supported by the industry, would need to be promulgated and enforced by State agricultural agencies.

## Mechanical Control

Mechanical control by mass trapping involves using the species-specific sex attractant and aggregation pheromone produced by the adult male boll weevil, which is attractive to both adult females and other adult males. A pheromone is a substance secreted by an animal that influences the behavior or physical development of animals of the same species. The boll weevil pheromone aids the female in finding mates and serves as a "tracer" to assist other males in finding cotton for feeding.

The nontoxic trap aggregation pheromone and sex attractant, given the name "grandlure," was isolated, identified, and synthesized by Tumlinson et al. (1969). Grandlure is a mixture of two terpenoid alcohols and two aldehydes (Tumlinson et al., 1969; 1971). Traps used

to capture adult boll weevils contain a small quantity (10 milligrams) of grandlure, along with a small quantity of an insecticide to ensure that captured weevils do not escape the trap. Insecticide strips containing propoxur or chlorpyrifos have been found to be effective in traps used for population monitoring purposes.

Field studies have shown that pheromone traps are effective in detecting boll weevil populations, especially the very small populations that may exist during early spring or following insecticide treatment (Lloyd et al., 1983). In the spring, traps are concentrated in brushy areas near field borders in sites where overwintering weevils are known or suspected to exist. This trapping is conducted to capture overwintering adults as they emerge from diapause, and it has been effective in suppressing very low populations of boll weevils. However, high-density trapping as a suppression technique is not considered operationally feasible because it is too labor intensive and costly.

Intensified in-field trapping may also be used in fields suspected of having only a few individual weevils. These may be fields in the final stage of eradication, fields that have become reinfested, or newly infested fields. However, intensified in-field trapping early in the season is difficult to maintain because of cultivation. Boll weevil presence is rarely detected by a grower's chance observance of feeding or egg-laying punctures on squares or bolls in fields where trap captures are zero. When boll weevils are detected, additional traps can be placed within the field. In the spring, this intensified trapping may eliminate small populations of emerging boll weevils. Later in the season, the technique is helpful in delimiting the infestation and in marking the infested portion of larger fields to assist aerial applicators.

### Sterile Insect Technique

The sterile insect technique involves the rearing, sterilization, and release of sterile weevils into fertile weevil populations. The sterile weevils mate with the wild (fertile) weevils, resulting in the production of nonviable eggs.

Previous attempts to use the sterile weevil technique have been hampered by high field mortality of sterile weevils and poor mating performance. This high mortality and poor vigor was believed to be caused by the extreme treatments required for sterilization. Dosages of radiation adequate to sterilize weevils also killed a large percentage of them. The weevils surviving the sterilization procedures were only 25 percent as competitive in field trials (that is, the weevils were 25 percent as vigorous and successful in mating as a normal, fertile weevil).

In a newer, more advanced technique, boll weevils are reared from eggs in an antiseptic atmosphere at the Robert T. Gast rearing facility on the campus of Mississippi State University. This facility currently is capable of rearing 5 to 6 million boll weevils per week. Following emergence, adult boll weevils are held for 5 days on a diet containing

100 parts per million (ppm) diflubenzuron and then exposed on the sixth day to 10 kilorads (krad) of gamma radiation from a Cesium-137 source in a nitrogen atmosphere (Wright and Villavaso, 1983). This procedure causes sterilization in 99.99 percent of both male and female weevils. Reproduction of adults treated in this manner is essentially zero; in field trials, treated weevils failed to establish detectable populations in a weevil-free area (Mitchell et al., 1980).

These rearing and sterilization procedures produce a boll weevil that has 70 percent the reproductive success of wild boll weevils. Although it was believed that a weevil 70 percent as competitive would perform satisfactorily in the field, the effectiveness of this technique had never been evaluated in a large-scale field trial (NRC, 1981).

The exact number of sterile weevils to be released in a given field depends on the size of the native population, the competitiveness of the sterile weevil, and the number of sterile weevils available from the production facility. Current research estimates—based on only a 25-percent-competitive weevil—indicate that a ratio of 8:1 of sterile to wild weevils must be maintained to effectively suppress a population (according to a personal communication with D. Hardee, Ph.D., U.S. Department of Agriculture, Agricultural Research Service). The primary barriers to achieving this ratio are the limited production capacity of the Mississippi State facility and the inability to accurately estimate the size of a native boll weevil population. Even with the availability of a more competitive weevil, it was believed that very large numbers of sterile weevils would be required to suppress a population.

In 1987 and 1988, field trials were conducted on 3,000 acres of cotton in Fayette County, Alabama. Sterile weevils were released at a rate of 300 to 400 adults per acre per week over a 10-week period. The number released was determined solely by the number available from the production facility. Before the sterile insects were released, the fields were treated with insecticides to suppress the wild weevil population. The initial release of the sterile weevils was made prior to the pinhead-square stage of cotton development, and a large population of sterile weevils was maintained throughout the growing season. Weekly monitoring, sorting, and identification of trapped weevils was necessary to evaluate whether a sufficiently large sterile population was being maintained within the targeted fields.

During both trial years, growers reported a reduced need for insecticide treatment and an absence of secondary pest problems on the trial fields. However, all of the trial fields reported at least 50 percent fertile matings in both years. Abnormally high late-season emergence, uneven dispersal of sterile weevils within the fields, and poor selection of trial fields (adjacent to wooded areas) may have contributed to the poor suppression of fertile matings (according to a personal communication with J. Smith, Ph.D., U.S. Department of Agriculture, Agricultural Research Service).

The inconclusive nature of these trials indicates that additional testing is necessary before the sterile insect technique can be considered a proven technology for boll weevil eradication. It is unlikely that this technique alone can be used to completely eliminate a large population. It may, however, be useful in suppressing small boll weevil populations, provided an adequate number of sterile boll weevils are available. Based on the current rearing capacity of the Mississippi State facility, up to 20,000 acres could be treated weekly with this technique. A much larger production facility would be required before this technique could be used more extensively throughout the Cotton Belt. Although the sterile insect technique may not be efficacious or cost-effective over the entire program area, it may play an important role in suppressing weevils in unique, localized areas of a future program.

## Chemical Control

Under the chemical control method, insecticides are used to control the boll weevil population in cotton-growing areas. The insecticides currently available for program use—malathion, azinphos-methyl, diflubenzuron, and methyl parathion—have been proven effective in controlling boll weevil populations and have been approved by the Environmental Protection Agency (EPA) for use on cotton. The methyl parathion formulation being considered for use in this program is microencapsulated; that is, the active ingredient of the insecticide methyl parathion is enclosed in microscopic capsules (20 to 25 microns in diameter) made of nylon polymers. Two other insecticides, chlorpyrifos and propoxur, are used only in weevil traps as impregnated strips. The organophosphate insecticides (malathion, azinphos-methyl, and methyl parathion) are equally effective in controlling boll weevils. The selection of a particular chemical therefore, is based on environmental and economic considerations. Application methods, as well as the timing and frequency of application, are described in the following sections.

***Aerial Application.*** Aerial application of ultra-low-volume (ULV) sprays for boll weevil control involves the use of airplanes or helicopters. The ULV application of pesticides is the application of less than 0.5 gallon per acre of spray liquid. Very small droplets are produced by special spray nozzles on the aircraft, and often special formulations of the pesticide are required to keep the chemical in solution. Compared to conventional spray formulations, significantly less ULV material is required to treat a given area. Consequently, treatment aircraft can carry a smaller load, consume less fuel, and treat more acres in less time. Another advantage of this method is that the effectiveness of controlling boll weevils is better than, or at least equivalent to, conventional methods.

Insecticides are applied by special nozzles on spray booms that are mounted near the trailing edge of the airplane wing or across and beneath the body of the helicopters. In general, aerial applications are

conducted as close to the ground as possible to minimize drift. In boll weevil control, aircraft typically fly 5 to 12 feet above the top of the cotton plants (the canopy) depending on the time of year and stage of growth. Swaths can range from 60 to 125 feet, depending on the type of aircraft, spray boom width, and height above the canopy. In a normal operation, the work crew includes the pilot and an application observer, but it may also include one or more flaggers to operate guidance markers. (EPA regulations prohibit the use of human flaggers during aerial application of any methyl parathion formulation.)

ULV spray applications will be considered for aerial use in the proposed control program. However, the small droplets required to achieve adequate coverage with the small amounts of applied liquid will increase the potential for spray drift. The extensive standard operating procedures described in table 2-1 will help to minimize the potential for offsite insecticide drift (the potential for offsite drift and potential impacts associated with drift are discussed in chapter 4). In addition, mitigation measures are proposed in table 2-2.

Over the past 9 years of program operation, managers have taken the initiative in developing mitigation measures. This has resulted in an extensive list of effective, field-tested mitigation measures, most of which are now being used.

EPA requires that pilots of agricultural aircraft be certified applicators if applying diflubenzuron, methyl parathion, or azinphos-methyl. A certified applicator is an individual who has demonstrated competence in the use and application of pesticides. These individuals receive special training in application methods designed to prevent adverse effects to the environment and procedures designed to promote worker safety. Some of these methods and procedures that are applicable to aerial application in the cooperative boll weevil control program are described in table 2-1. Most States also require certification of aerial applicators for malathion application. Only certified aerial applicators will be used in the cooperative control program.

Applications are monitored to determine whether all target areas have been treated satisfactorily, or if localized retreatments are necessary. If insecticide application to an area cannot be physically observed, appropriate oil-sensitive dye cards can be used to determine the uniformity and adequacy of the application. Dye cards are also used to monitor the accuracy of applications near sensitive areas.

Weather conditions are a factor in determining when aerial applications are conducted. Under some conditions, aerial applications may be inappropriate. Weather conditions may reduce the effectiveness of the operation or increase the likelihood of substantial offsite drift. Aerial operations are not conducted when winds exceed 10 miles per hour, or when rain is falling or is imminent and there is an increased potential for insecticide runoff. (In States where wind speed limitations are more restrictive, program cooperators comply with those restrictions.) Aerial

## Table 2-1. Operational Procedures

### All Methods of Control

1. All applicable Federal, State, and local environmental laws and regulations will be followed during boll weevil control operations.

2. Sensitive areas (water bodies; parks; and occupied dwellings, such as homes, schools, churches, hospitals, and recreation areas) that may be adjacent to cotton fields will be identified. The program will be adjusted accordingly to ensure that these areas are not negatively affected.

3. Environmental monitoring of programs will be in accordance with the current environmental monitoring plans.

4. All cotton fields in each program increment will be trapped, but only fields meeting the program criteria will be treated.

5. All program personnel will be instructed in the use of equipment and materials and on operational procedures. Field supervisors will emphasize these procedures and monitor the conduct of personnel.

### Aerial Applications

1. All materials will be applied in strict accordance with EPA- and State-approved label instructions.

2. Aircraft, dispersal equipment, and pilots that do not meet all contract requirements will not be allowed to operate.

3. All USDA APHIS Plant Protection and Quarantine employees who plan, supervise, recommend, or perform pesticide treatments must be certified under the APHIS pesticide certification plan. They also are required to know and meet any additional requirements or qualifications of the State where they perform duties involving pesticide use.

4. Unprotected workers will be advised of the respective reentry periods following treatment. If azinphos-methyl is used, unprotected workers will not reenter the field for 24 hours; following a methyl parathion treatment, unprotected workers will not reenter the field for 48 hours.

5. Two-way radios will be provided to personnel who direct or coordinate field operations. Radio communication will be available to provide close coordination of all application operations.

6. All APHIS field personnel will have baseline cholinesterase tests before the first application and each spring and fall thereafter. It is recommended that contract, State, and private personnel also participate in this testing program.

7. Only certified aerial applicators who have been familiarized with local conditions will be used by the program.

8. To minimize drift and volatilization, application will not be made when any of the following conditions exist in the spray area: wind velocity exceeding 10 miles per hour (or less if required by State law); rainfall or imminent rainfall; foggy weather; air turbulence that could seriously affect the normal spray pattern; or temperature inversions that could lead to offsite movement of spray.

9. Nozzle types and sizes, spray system pressure, and nozzle orientation will be as specified in the program's aerial application contract or as otherwise directed by program personnel.

**Table 2-1. Operational Procedures (continued)**

**Ground Applications**

1. Mist Blowers:

   - Operators either will be certified applicators or will be in constant radio contact with certified applicators.

   - Units will be operated from closed truck cabs, with operators using recirculated air.

2. High-Clearance Machines:

   - Operators either will be certified applicators or will be in constant radio contact with certified applicators.

   - Units will be operated from closed truck cabs, with operators using recirculated air.

**Table 2-2. Recommended Mitigation Measures**

All required State and local authorities will be notified upon initiation of the program. The notification will advise State and local authorities of the need for assistance in identifying sensitive areas in proposed treatment areas.

**Protection of Workers**

All program personnel will be instructed on emergency procedures to follow in the event of insecticide exposure. Equipment necessary for immediate washing procedures must be available for application personnel.

**Aerial Applications**

1. Pilots, loaders, and other personnel handling insecticides will be advised to wear safety equipment and protective clothing.

2. Program personnel observing applications of malathion and azinphos-methyl or methyl parathion are required to wear protective clothing or remain inside a closed vehicle with recirculating air, depending on circumstances of the application.

3. Application operations will be postponed in fields occupied by workers.

4. Flags or other markers will be used for pilot guidance in areas without natural landmarks.

**Ground Applications**

1. **Mist Blower**

    - Units will be operated from closed cabs, with operators using recirculated air.

    - Operators will wear appropriate safety equipment when loading or servicing the unit and will be specially trained by program personnel.

2. **High-Clearance Machines**

    - Operators *must* be certified applicators for methyl parathion applications, and they will exercise extreme caution when applying this material.

    - Operators will wear appropriate safety equipment and protective clothing when loading, servicing, and operating the unit.

**Pesticide Handling Precautions**

1. To the degree possible, insecticides will be delivered and stored in sealed bulk tanks and then pumped directly into the aircraft.

2. All insecticides will be stored in accordance with Federal, State, and local regulations and label instructions.

3. All mixing, loading, and unloading of insecticides will be in an area where an accidental spill will not contaminate a stream or other body of water.

4. In the event of an accidental spill, procedures set forth in *PPQ Guidelines for Managing and Monitoring Pesticide Spills* (USDA-APHIS-M390-1402, 1983) will be followed.

5. All insecticide drums must be triple-rinsed before disposal. Rinse solutions may be used to prepare spray tank mixes or may be stored for subsequent disposal in accordance with label instructions. One of the following methods of drum disposal must be used:

   - Require chemical companies, distributors, or suppliers to accept empty triple-rinsed drums.

   - Transfer the empty triple-rinsed drums to State cooperators.

   - Crush and/or puncture the empty triple-rinsed drums and dispose of as scrap metal.

**Protection of Public**

1. Application aircraft shall avoid direct spraying of residences, garden plots, and adjacent crops at all times. Methyl parathion shall not be sprayed within 100 feet of a garden plot.

2. Program personnel shall notify area residents not to consume fish from farm ponds located less than 50 feet from cotton fields treated with methyl parathion.

3. Program personnel shall immediately cease spraying operations if members of the public are observed within 100 feet of a cotton field being sprayed with malathion, azinphos-methyl, or methyl parathion.

**Protection of Bees**

Before beginning treatment with malathion, azinphos-methyl, or methyl parathion, program personnel shall notify all registered apiarists in or near the treatment area of the date and approximate time of chemical treatment.

**Protection of Wildlife**

1. All control operations will be conducted with appropriate concern for their potential impact on the endangered, threatened, and proposed species identified in this document.

   - APHIS has prepared a biological assessment for federally listed endangered, threatened, and proposed species found within all U.S. cotton-producing counties from species information provided by the U.S. Department of the Interior, Fish and Wildlife Service (FWS).

   - Adequate protection measures are being developed for federally listed endangered, threatened, and proposed species through Endangered Species Act, Section 7, formal consultations with FWS. Specific biological and distributional data for species will be gathered in discussions between APHIS Plant Protection and Quarantine (PPQ) and local FWS offices before operations begin.

   - Species and habitats protected by State laws will be addressed in site-specific assessments as needed.

2. Oil- or water-sensitive dyecards will be used to regularly monitor application efficacy. Spray deposition in the target area and droplet size are critical concerns.

applications are also not conducted when temperature inversions can lead to offsite drift. Tables 2-1 and 2-2 include operational procedures and mitigation measures designed to minimize drift.

*Ground Application.* When aerial application is impractical or inappropriate, malathion, azinphos-methyl, methyl parathion, and diflubenzuron may be applied by high-clearance ground equipment (called "hiboys"), and by truck-mounted mist blowers. Ground applications can be made on cotton around field borders, near tall trees, under utility wires, and in areas adjacent to sensitive areas. Applications by high-clearance ground equipment are made with spray nozzles adjusted to an optimal height of 6 inches above the cotton canopy, thereby minimizing the potential for chemical drift. Height above the canopy may vary 1 or 2 inches depending on the brand of equipment.

High-clearance ground equipment can potentially treat an entire field, but only if the ground is firm and the crop is not fully mature. Such equipment has the potential to damage mature cotton. This equipment may be used to apply the ULV formulation of diflubenzuron, the RTU (ready-to-use) and ULV formulations of malathion, all proposed formulations of azinphos-methyl, and a mixture of water and the encapsulated formulation of methyl parathion.

Truck-mounted mist blowers provide accurate placement of pesticides and under optimum conditions can effectively cover a 40-foot swath, or approximately 14 rows of cotton. Mist blowers are used primarily along protected field borders and other areas not easily treated by aerial application. They cannot be used to treat an entire field because of limited accessibility to the interior of the field. The efficacy of mist blowers is influenced by terrain, cotton height, and wind direction. They may be used to apply the same formulation of ULV-grade malathion used in aerial application, the ULV formulation of diflubenzuron, all proposed formulations of azinphos-methyl, and a mixture of water and the encapsulated formulation of methyl parathion.

*Determining the Need for Chemical Treatment.* The need for chemical treatment and the number of chemical treatments required are determined using information gained through pheromone trapping and field surveillance. This information can also be used to detect and monitor boll weevil movement, identify and predict problem areas for treatment, evaluate treatment effectiveness, and identify those fields that do not require chemical treatment.

Boll weevil populations are detected and monitored using commercially produced pheromone traps containing grandlure. The trap density in a given field is based on its proximity to overwintering sites and total acreage. In the chemical control method, traps are used primarily for detection and monitoring and for early season suppression. Trap densities range from one trap per acre to one trap per 10 acres. In the spring, traps are positioned on the edges of fields near brush and debris that the weevils use as overwintering sites. This allows

supervisory personnel to evaluate the size of populations emerging from dormancy. Traps are positioned around the field perimeter 4 to 5 weeks before the pinhead-square stage of cotton development. The number of trapped weevils is used to estimate the relative abundance and distribution of the population and to determine the need for spring treatments.

The number of trapped weevils is also used to identify heavily infested fields, fields likely to sustain economic crop damage, and fields with relatively few boll weevils. The threshold number of weevils trapped per field, which is used to indicate the need for chemical treatment, varies according to location within the Cotton Belt and the stage of cotton and weevil development.

Generally, low thresholds (two weevils per 40-acre field per week) are used to trigger spring treatments in areas in which an eradication program is in progress. Later in the season, the threshold could increase to five weevils per 40-acre field per week. At that time, the objective of treatments is to prevent economic damage to the cotton crop and to contain the local infestation by preventing its spread to adjacent fields. Cotton is producing an abundance of fruit at this time and provides weevils with an ample food supply. Eliminating a weevil population at this point in the season can be very difficult. In the fall, the weevil becomes more vulnerable: Cotton growth is ending, defoliants are applied by growers, temperatures drop, and the weevil's food supply diminishes. At this time of year, weevils begin to migrate in search of food. An adequate supply of food is necessary if the weevil is to store sufficient body fat to survive until the next season's crop is available. Many of the weevils observed each fall will die before the next spring. For this reason, treatment thresholds can be raised to about 10 weevils per 40-acre field per week during the fall.

If the weevil trap catch meets or exceeds the threshold in a program area, a single chemical treatment is applied, followed by a second treatment 7 days later. Applications continue as long as thresholds are exceeded.

***Frequency and Timing of Chemical Treatments.*** Application frequency is determined by the degree of infestation in the fields. Heavily infested fields may require treatment at 3-day intervals (for usually no more than 2 to 3 weeks) to break the reproductive cycle. Fields with lower numbers of weevils may receive only one or two treatments during an entire year. Fields that do not exceed the threshold are not treated.

Future increments of an eradication program may begin with three to five treatments in the fall of the first year. An average field may receive six to eight chemical treatments the following season. The most heavily infested fields, however, may require as many as 25 treatments. (In previous eradication efforts, this higher number has applied to fewer than 2 in every 1,000 program fields.) In the West Texas Containment Program, the number of treatments required is generally two

to four each fall. In full-season suppression programs, average fields might require four to six treatments every year. Chemical treatments are applied as needed in a full-season suppression program during spring, summer, or fall.

Spring treatments applied at the pinhead-square stage of cotton development are targeted at the initial reproducing weevil population. Applications are timed to occur before the overwintered female weevils begin laying eggs; and if treatments are terminated early enough, beneficial insect populations can recover and contribute to the control of secondary pests (Parencia et al., 1983). Organophosphate insecticides are used in early spring to kill the overwintered weevils before they can reproduce.

Diflubenzuron may also be used in spring treatments. Diflubenzuron controls boll weevils by inhibiting the production of chitin, a key structural component in the insect exoskeleton. Female adult boll weevils that contact or feed on diflubenzuron lay eggs that do not hatch. However, the effect of diflubenzuron is transitory, and females regain their fertility in 7 to 10 days if not exposed to frequent, timely retreatment. Therefore, a series of such treatments would occur over a 3- to 4-week period and would be followed by an organophosphate treatment to eliminate the population before it could regain fertility.

Midseason treatments are designed to contain the population and prevent economic damage to the crop; they are not intended to eliminate a population. Midseason treatments frequently contribute to the secondary pest problem, but such treatments may be necessary in some fields to prevent economic damage to the crop and further distribution of the pest. Organophosphate insecticides are used for midseason treatments.

Fall, or diapause, treatments are timed to suppress the number of weevils entering diapause and to limit reproduction in the last generation of weevils in late summer and early fall. The overall effect of these treatments is a reduction in the number of adults emerging the following spring (Parencia et al., 1983). Organophosphate insecticides are applied at 5- to 21-day intervals during this period, in accordance with temperatures and crop conditions.

### Chemicals Considered for Aerial and Ground Applications

This section briefly describes the six insecticides under consideration by APHIS for controlling boll weevils. These chemicals were selected for analysis because they have been proven effective in controlling boll weevil populations, are approved by EPA for use on cotton, are commonly used by growers for boll weevil control, and are economically and operationally feasible for use in large-scale programs. Table 2-3 lists the trade names, active ingredients, and application methods and rates proposed by APHIS for use in control programs. The primary insecticides are malathion, azinphos-methyl, diflubenzuron, and methyl

## Table 2-3. Insecticide Trade Names, Active Ingredients, and Application Methods and Rates

| Insecticide | Trade name/formulation (percent active ingredient) | Application rate (lb a.i./acre) | Application method | Active ingredient |
|---|---|---|---|---|
| Malathion | Cythion® RTU[a] (45.1) | 1.17[b] | RTU ground equipment | O,O-dimethyl phosphorodithioate of dimethyl mercaptosuccinate |
| | Cythion® ULV[a] (91) | 1.17 | ULV aerial and ground | |
| | Fyfanon® ULV[c] (95) | 1.17[d] | ULV aerial and ground | |
| Azinphos-methyl | Guthion® 2S[e] (22) | 0.25 | ULV aerial and ground | Phosphorodithioic acid, 0,0-dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)methyl] ester |
| | Guthion® 2L[e] (22.2) | 0.25 | ULV aerial and ground | |
| | Lanco Azinphos methyl 2EC[f] (22.2) | 0.25 | ULV aerial and ground | |
| | Clean Crop®[g] Azinphosmethyl 2 (22.2) | 0.25 | ULV aerial and ground | |
| Diflubenzuron | Dimilin® 25W[h](25) | 0.125 | ULV aerial and ground | N-[[(4-chlorophenyl) amino]carbonyl]-2,6-difluorobenzamide |
| | Dimilin® 2F[h] (24) | 0.125 | ULV aerial and ground | |
| Methyl parathion | Penncap M®[i] (20.9) | 0.5 | Aerial[j] (encapsulated) Ground equipment | Phosphorothioic acid, 0,0-dimethyl 0-(4-nitrophenyl) ester |
| Propoxur | Baygon®[k] | NA[l] | Laminated insecticide strip | O-isopropoxyphenyl N-methylcarbamate |
| Chlorpyrifos | Dursban®[m] | NA[l] | Laminated insecticide strip | 0,0-Diethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate |

[a] Cythion is a registered trademark of the American Cyanamid Company.
[b] Except in West Texas Containment Program, which uses 12 oz/acre (0.85 lb a.i./acre).
[c] Fyfanon is a registered trademark of A/S Cheminova, Lemvig, Denmark.
[d] Early and midseason application rate is 0.92 lb a.i./acre.
[e] Guthion is a registered trademark of the Mobay Chemical Corporation, Kansas City, MO.
[f] Lanco Azinphos methyl 2EC is produced by Landia Chemical Company, Lakeland, FL.
[g] Clean Crop is a registered trademark of United Agri Products, Inc.
[h] Dimilin is a registered trademark of Duphar B.V., Weesp, the Netherlands.
[i] Penncap M is a registered trademark of Pennwalt Corporation, Philadelphia, PA.
[j] Aerial application of low-volume sprays of Penncap M® is prohibited in California.
[k] Baygon is a registered trademark of the Bayer Company, New York.
[l] Minute amounts of these materials may be enclosed in pheromone traps; these materials will not be used in spraying operations.
[m] Dursban is a registered trademark of the Dow Chemical Company, Midland, MI.

parathion. Information also is given for the chemicals propoxur and chlorpyrifos, which are used in weevil traps. The application rates provide the basis for estimating the potential exposure to humans, wildlife, and other nontarget organisms from these chemicals. Each of the selected chemicals is briefly described below. Detailed descriptions of the environmental fate and transport and the toxic properties of the chemicals are found in appendix B.

***Malathion.*** Malathion, a broad-spectrum organophosphate insecticide, was first used in the United States in 1950. It currently is used to control a wide variety of insects, including the boll weevil; it is also used on beef cattle; on grain and vegetable crops, forests, pastures, and rangelands; and in homes and gardens. It has been used in several major insect control programs, including programs to control mosquitoes, the spruce budworm, and the Mediterranean fruit fly.

Malathion is a colorless, yellow-amber or brown liquid with a rotten-egg odor. Three malathion formulations are being considered for use. Cythion® ULV concentrate contains 91 percent malathion and 9 percent inert ingredients. Cythion® RTU contains 45.1 percent malathion and 54.9 percent inert ingredients. Both are manufactured by American Cyanamid Company. Fyfanon® ULV concentrate contains 95 percent malathion and 5 percent inert ingredients. Fyfanon® ULV is a product of A/S Cheminova-Lemvig-Denmark.

In soil, malathion is broken down relatively quickly by moisture and the action of soil microorganisms. It has a moderate tendency to adhere to soil particles, but has been found in groundwater. Its soil half-life (the time for 50 percent of the initial amount to break down) is 3 days.

Malathion has a half-life on vegetation of 3 days. Sunlight does not cause a significant amount of malathion degradation as it does with some other chemicals. The speed of degradation in aquatic environments is dependent on temperature and pH. Breakdown is more rapid in warm, basic water as opposed to cold, acidic waters. Half-lives in aquatic environments range from less than 1 day to more than 4 months.

For mammals, pure malathion is mildly irritating to the eyes and skin. Like other organophosphorus compounds, it can adversely affect the transmission of nerve impulses. There is no conclusive evidence regarding potential carcinogenicity of malathion, although one of its metabolites, malaoxon, is a potential carcinogen. Some commercial formulations are highly toxic to fish. Malathion is highly toxic to aquatic invertebrates and terrestrial invertebrates, such as bees, and moderately toxic to birds.

***Azinphos-methyl.*** Azinphos-methyl is a broad-spectrum organophosphate insecticide, acaricide, and molluscicide. It has been available in the United States since 1956 for use on field, vegetable, fruit, cereal, and

ornamental crops. One of its major applications is control of cotton pests, especially the boll weevil and pink bollworm.

Pure azinphos-methyl is a yellow-brown, waxy solid with a mild odor. Guthion® 2L, manufactured by Mobay Chemical Company, is an emulsifiable liquid containing 22.2 percent (2 lb/gal) azinphos-methyl, 59.8 percent aromatic petroleum distillates, and 18 percent inert ingredients. Guthion® 2S, another Mobay product, is also an emulsifiable formulation that contains 22 percent azinphos-methyl, 52 percent aromatic petroleum distillates, and 26 percent inert ingredients. This formulation stays in emulsion at lower temperatures than the 2L formulation, making it more appropriate for use in early spring and late fall. Lanco Azinphos methyl 2EC, manufactured by Landia Chemical Company, is an emulsifiable liquid containing 22.2 percent azinphos-methyl and 77.8 percent inert ingredients. Clean Crop® Azinphosmethyl 2, manufactured by Platte Chemical Company, is an emulsifiable liquid containing 22.2 percent azinphos-methyl, 45.2 percent aromatic petroleum distillates, and 32 percent inert ingredients.

Azinphos-methyl, with a soil half-life of approximately 12 days, does not appear to be persistent in the soil environment. However, based on its physical and chemical characteristics, it is expected to be moderately mobile in soil. In aquatic environments, breakdown by bacteria appears to be the principal degradative process. Azinphos-methyl appears to be more persistent on vegetation than other organophosphate insecticides.

Available data indicate that azinphos-methyl is very highly toxic to mammals, including humans. It has not been conclusively determined whether or not it is a carcinogen. In mammals, it is metabolized primarily to dimethyl thiophosphate and excreted in the urine. It is also very highly toxic to freshwater invertebrates, moderately to very highly toxic to freshwater fish, and moderately toxic to several bird species.

***Diflubenzuron.*** Diflubenzuron is an insect growth regulator that inhibits chitin production, preventing the formation of new exoskeleton material in insects. It is registered for use on cotton, irrigated pastures, soybeans, greenhouse mushrooms, ornamental and shade trees, forests, and Christmas tree plantations. The pests controlled by diflubenzuron include the boll weevil, mosquito, gypsy moth, and mushroom fly.

Pure diflubenzuron is an odorless, white crystalline solid. Dimilin® 25W is a wettable powder containing 25 percent diflubenzuron and 75 percent inert ingredients. Dimilin® 2F is a liquid containing 24 percent diflubenzuron and 76 percent inert ingredients. Both are manufactured by Duphar B.V. of Amsterdam, Holland, and distributed by the Uniroyal Chemical Company.

Diflubenzuron degrades fairly rapidly in soil, mainly through the action of microorganisms. Its half-life is less than one-half week to 1 week. It is also relatively nonpersistent in aquatic environments, unless very acidic conditions exist. In shallow ponds, a half-life of 0.4 to 1.4 days has been reported.

Diflubenzuron has a low acute toxicity to mammals. At toxic doses, it interferes with oxygen transport in the bloodstream to body tissues. There is no conclusive evidence on potential carcinogenicity. Diflubenzuron has low toxicity to birds, finfish, and honey bees, but it is extremely toxic to aquatic invertebrates.

***Methyl Parathion.*** Methyl parathion is a broad-spectrum organophosphate insecticide. Foliar application using ground equipment or aircraft is the usual method of application. (California, however, prohibits aerial application of microencapsulated methyl parathion.) This chemical is used on food and nonfood crops and in forestry to control many insects, and on cotton to control the boll weevil.

Methyl parathion is a white crystalline solid or powder with an odor like rotten eggs or garlic. Penncap M®, manufactured by Pennwalt Corporation, contains 20.9 percent (2 lb/gal) microencapsulated methyl parathion, 1.1 percent related isomers, 4.9 percent xylene base aromatic solvent, and 73.1 percent inert ingredients. In the microencapsulated formulation, the active ingredient of the insecticide, methyl parathion, is enclosed in microscopic capsules (20 to 25 microns in diameter) made of nylon polymer.

Methyl parathion has a low leaching potential. It biodegrades rapidly in soil, with a half-life of 5 days. In aquatic systems, it is completely degraded in 2 weeks to 2 months. Its foliar half-life is 3 days.

Methyl parathion is highly toxic to mammals. It has demonstrated mutagenic and genotoxic properties, but it is not considered to be carcinogenic. EPA regulations prohibit the use of human flaggers during aerial application operations. It is highly toxic to aquatic invertebrates and birds and moderately toxic to fish and other species. According to studies by Pennwalt Corporation, the encapsulated formulation of methyl parathion is less acutely toxic to mammals, both orally and dermally, than the liquid and emulsifiable concentrate formulations. However, no long-term studies using the encapsulated formulation are available. The Penncap M® formulation is highly toxic to bees.

### Chemicals Considered for Use in Traps

***Propoxur.*** Propoxur is a broad-spectrum insecticide used both agriculturally and domestically to control mosquitoes, flies, fleas, ticks, ants, cockroaches, aphids, and leafhoppers.

Technical propoxur is a white or tan crystalline solid with a faint characteristic odor. Insectape® insecticidal strips contain 10 percent propoxur and 90 percent inert ingredients.

Propoxur is relatively persistent in terrestrial systems. Breakdown is predominantly by the activity of soil microorganisms.

Propoxur can adversely affect the transmission of nerve impulses and is a probable human carcinogen. It is also toxic to bees. Propoxur is not approved for foliar or aerial application in boll weevil control and there is no intention to use it for that purpose in a cooperative control program. The use of propoxur would be limited to small strips enclosed in boll weevil traps.

***Chlorpyrifos.*** Chlorpyrifos is a broad-spectrum insecticide with many domestic and agricultural uses. Spot treatments and impregnated materials are used to control indoor pests, including cockroaches, ants, mosquitoes, spiders, ticks, and mites. Other uses include foliar and aerial applications to food and feed crops and direct applications to animals. It may also be used to control several cotton pests, including the boll weevil, bollworm, cotton fleahopper, and armyworm. However, in the proposed control program, chlorpyrifos would be limited to use as a killing agent in pheromone traps.

Technical chlorpyrifos is a white crystalline solid with a mild rotten-egg odor. It was developed in the early 1960s by Dow Chemical Company.

The reported soil half-life for chlorpyrifos is 68 days. It has a low leaching potential. In natural waters, it has a half-life of approximately 1.5 days. It is subject to degradation by light, which may decrease its half-life in soil to as low as 30 days.

Chlorpyrifos is extremely toxic to fish, birds, and other wildlife. It is also of toxic concern to mammals. However, its use in the program would be limited to small impregnated strips enclosed in boll weevil traps. It is not being considered for foliar treatment.

## Summary of Impacts of Control Methods

A summary of the environmental impacts of control methods for each resource element is listed in table 2-4. An extensive analysis of the risks associated with using chemical control is in appendix B.

## Control Methods Eliminated From Detailed Study

Two control methods, biological agents and resistant plant varieties, were eliminated from detailed study because they have not yet demonstrated adequate control effectiveness throughout the entire Cotton Belt. An explanation of these methods and the reasons they were eliminated are discussed in the following sections.

**Table 2-4. Summary of Potential Environmental Impacts of Control Methods by Resource Element**

| Control methods | Soils | Vegetation | Water quality | Nontarget terrestrial species |
|---|---|---|---|---|
| **Cultural control** | Increased erosion potential caused by removal of host plant material. | Slight impact on adjacent vegetation due to migration of secondary pests from treated fields. | Slight impact due to potential increase in runoff and sedimentation due to erosion. | Temporary disturbance due to noise, dust, and vibration. Risk of injury or fatality due to passage of heavy equipment. |
| **Physical control** | No impact. | No impact. | No impact. | No impact. |
| **Sterile insect release** | No impact. | No impact. | No impact. | No impact. |
| **Chemical control** | No significant impact. Insecticides quickly degrade. Chemicals strongly adsorbed to soil particles. Microorganism populations quickly regenerate. | No direct impact. Insecticides not phytotoxic. Temporary impacts on pollinator-dependent vegetation due to potential reduction of foraging bees and other pollinators, depending on chemical used. | No long-term impact. Insecticides quickly degrade. | Potential significant impact on terrestrial wildlife and insects. Degree of impact dependent on chemical selected and method of application. |
| Malathion | | | | No significant impact on most terrestrial species. Significant risk to honey bees and other beneficials from direct spray. |
| Azinphos-methyl | | | | Risk of adverse effects on several avian, mammalian, and insect species exposed to direct spray or spray drift. |
| Diflubenzuron | | | | No significant impact on terrestrial species. |
| Methyl parathion | | | | Risk of adverse effects on several avian, mammalian, and insect species exposed to direct spray or spray drift. |

**Table 2-4. Summary of Potential Environmental Impacts of Control Methods by Resource Element (continued)**

| Control method | Nontarget species—Aquatic | Human—Public | Human—Workers |
|---|---|---|---|
| **Cultural control** | Slight potential for temporary adverse effects due to increased turbidity of surface water from erosion. | No significant impact. | Slight risk of accidents in operation of heavy equipment. Slight potential for upper respiratory irritation from dust for sensitive individuals. |
| **Physical control** | No impact. | No impact. | No impact. |
| **Sterile insect release** | No impact. | No impact. | No impact. |
| **Chemical control** | Potential for significant impact on aquatic species. | Potential for slight to moderate systemic and/or reproductive effects. Degree or existence of risk dependent on chemical selected and method of application. Negligible carcinogenic risk to the public. Mitigation reduces risk to acceptable levels. | Potential for slight to significant systemic and/or reproductive effects. Degree or existence of risk dependent on chemical selected and method of application. Limited carcinogenic risk from accidents only. Mitigation reduces risk to acceptable levels. |
| Malathion | Risk of adverse effects on aquatic species in farm ponds located near cotton fields or in rivers or streams receiving runoff. | Slight risk for consumption of fish in the extreme scenario. Mitigation reduces risk to acceptable levels. Carcinogenic risks are negligible. | Slight to moderate risk of systemic effects for ground applicators. In extreme scenarios, slight to moderate risk of systemic effects to mixer/loaders. Risk for all workers with the exception of environmental monitoring team for routine scenario and worker accidents. Mitigation reduces risk to acceptable levels. |

**Table 2-4. Summary of Potential Environmental Impacts of Control Methods by Resource Element (continued)**

| Control method | Nontarget species—Aquatic | Human—Public | Human—Workers |
|---|---|---|---|
| Azinphos-methyl | Risk of adverse effects on fish and aquatic species in farm ponds near cotton fields or streams and rivers receiving runoff or spray drift. | Potential for slight to moderate systemic effects from consumption of contaminated fish. Slight to moderate risk of systemic effects from accidents. Negligible carcinogenic risk. Mitigation reduces risk to acceptable levels. | Slight to moderate risk of systemic effects for mixer/loaders, pilots, and observers. Moderate to significant risk for ground applicators. Low-level carcinogenic risk for ground applicators. In extreme scenarios, moderate risk of reproductive effects for ground applicators. Severe risk of systemic and significant risk of reproductive effects from worker accidents. Mitigation reduces risk to acceptable levels. |
| Diflubenzuron | Risk of adverse effect to aquatic invertebrates. | Slight risk for consumption of fish in the extreme scenario. Mitigation reduces risk to acceptable levels. | Moderate to significant risk of systemic effects for ground applicators. Significant risk of systemic effects for workers from accidents. Low-level carcinogenic risk for ground applicators and worker accidents (carcinogenic potential of diflubenzuron is uncertain). Mitigation reduces risk to acceptable levels. |

Table 2-4. Summary of Potential Environmental Impacts of Control Methods by Resource Element (continued)

| Control method | Nontarget species—Aquatic | Human—Public | Human—Workers |
|---|---|---|---|
| Methyl parathion | Significant risk to aquatic invertebrates exposed to direct spray or spray drift. | Significant risk for consumption of fish in the typical and extreme scenarios. Slight to moderate risk for consumption of water, venison, legumes, and berries in extreme scenario. Moderate risk of reproductive effects from accidents. Mitigation reduces risk to acceptable levels. | Moderate risk of systemic and slight to moderate risk of reproductive effects in typical and extreme scenarios for the pilot, mixer/loader, and observer. Significant risk of systemic and risk of systemic and reproductive effects for ground applicators. Severe risk of systemic and reproductive effects and risk of mortality from worker accidents. Mitigation reduces risk to acceptable levels. |

## Biological Agents

***Predators and Parasites.*** Predators, parasites, and microbial pathogens (viruses, bacteria, and fungi) provide natural biological suppression of many insect species that would otherwise be pests of agricultural crops. In cotton, for example, potential pests such as the beet armyworm (*Spodoptera* spp.), the cabbage looper (*Trichoplusia ni* (Hübner)), the bollworm (*Heliothis zea* (Boddie)), and the tobacco budworm (*Heliothis virescens* (Fabricius)), are frequently suppressed to densities that cause no significant damage (Ables et al., 1983; Bell, 1983). Use of these biological agents is usually referred to as "biological control by natural enemies" (DeBach, 1974). Suppression programs that use these biological agents normally attempt to protect these agents by limiting insecticide treatments for pest control whenever and wherever possible (DeBach, 1974; Metcalf, 1980). Other pest control programs rear and release large numbers of natural enemies within the target crop (Ridgway and Vinson, 1977).

While a number of predators, parasites, and pathogens have been found to attack the boll weevil (Ables et al., 1983), none have produced effective, reliable control of boll weevil populations in cotton crops within the United States. Recent research efforts have focused on a search for biological agents in Central America and Mexico, the original sources of the boll weevil infestation in the United States. Unfortunately, predator and parasite effectiveness differs in various cotton-growing regions, and a control agent imported from a tropical climate may not be effective in the temperate Cotton Belt (Reynolds et al., 1982). Thus, the reliance on biological agents for boll weevil control remains impractical pending the discovery of more effective natural enemies of the weevil.

## Resistant Plant Varieties

A plant variety (cultivar) is resistant to a given pest if, when all varieties are equally challenged by the pest, it produces a larger crop of satisfactory quality than other varieties. Plant resistance to insects is usually complex and varies with each insect and crop.

Most resistant cotton varieties display "ambivalence," which means that the variety is more resistant to the attack of one pest, but more susceptible to the attack of another pest. In most cases, the increased susceptibility to other cotton pests limits the acceptance of ambivalent varieties among growers. The most commonly discussed resistant varieties include "frego bract," "red color," and "oviposition factor."

Frego bract is a twisted bract mutant that inhibits boll weevil feeding and egg laying. In cotton having the frego bract trait, the bract does not tightly surround the flower bud, as it does in normal cotton strains. The more exposed flower bud allows for increased penetration of insecticides and increased mortality of boll weevil larvae. The bud exposure also allows for increased biological control by the parasitic

wasp (*Bracon mellitor* (Say)) (Namken et al., 1983). Frego bract varieties, however, have not become commercially feasible because of the extreme susceptibility of these varieties to plant bugs (*Lygus* spp.) (Jones, 1972).

Boll weevils are not attracted to the color red and shun red cotton varieties (Namken et al., 1983; Cross, 1983). Red leaf strains are highly resistant to boll weevil attack, but they currently have lower yields than commercial cotton varieties. Red stem varieties have comparable yields, but they are not as resistant to boll weevil attack.

Other cotton cultivars demonstrate resistance because of an "oviposition factor." This trait is found in primitive and predominantly tropical varieties and may be a promising source of resistance that could be bred into commercial cultivars. Varieties that possess this trait appear to be less susceptible to egg laying (Reynolds et al., 1982).

No red plant color or oviposition factor cultivars are commercially available for grower use. Cultivars that have these traits and that give acceptable agronomic performance over wide geographic areas have not been developed (Namken et al., 1983).

Biological agents and resistant plant varieties have not yet demonstrated adequate control effectiveness throughout the entire Cotton Belt. For this reason, it is not feasible to rely on such biological controls in a large cooperative control program, and these control methods have been eliminated from detailed analysis.

## Program Alternatives

The types of programs available for control of the boll weevil throughout the Cotton Belt can be grouped into three broad program alternatives for detailed analysis: no action (that is, no control by APHIS), beltwide eradication of the boll weevil, and beltwide suppression of the boll weevil. Under both the eradication and suppression alternatives, full and limited Federal participation options are analyzed. This section describes each of these alternatives and the control methods that could be components of each. Table 2-5 shows the control methods that could be used in the program alternatives.

### Alternatives Selected for Detailed Study

#### Alternative 1—No Action

Under the no action alternative, APHIS would neither fund nor participate in any program to control boll weevils in the Cotton Belt. Although the Cooperative Extension Service may continue to offer technical assistance, any active control of the pest would be left to the discretion of Cotton Belt States, grower associations, and individual cotton growers.

National Environmental Policy Act (NEPA) regulations require an agency to consider the no action alternative, even if the agency is under court order or legislative direction to act (46 FR 18026-18038, March 23, 1981). The analysis of the no action alternative provides a benchmark

**Table 2-5. Use of Control Methods in Program Alternatives**

| Control method | No action[a] | Eradication | | Suppression | |
|---|---|---|---|---|---|
| | | Full | Limited | Full | Limited |
| **Cultural[b]:** | | | | | |
| Short-season techniques | 2 | 2 | 2 | 2 | 2 |
| Stalk destruction | 2 | 1 | 1 | 2 | 2 |
| Trap cropping | 2 | 3 | 3 | 2 | 2 |
| Crop rotation | 2 | 2 | 2 | 2 | 2 |
| Production limitations | 3 | 2 | 2 | 3 | 3 |
| **Physical** | 3 | 2 | 2 | 3 | 3 |
| **Sterile insect technique** | 3 | 2 | 2 | 3 | 3 |
| **Chemical** | 1 | 1 | 1 | 1 | 1 |

[a] Control methods that may be used by growers only.
[b] Use of several of these cultural controls must be mandated by State agricultural agencies.

Note: 1 = Generally incorporated into control program.
2 = Could have limited use in control program, depending on efficacy and cost.
3 = Not expected to be used in control program.

or baseline against which the impacts of the other alternatives can be measured. The description of this alternative also represents current insect control as practiced in various Cotton Belt States.

Boll weevil control as now practiced by producers ranges from no control to intensive treatment with insecticides (USDA, 1981). Although most growers rely on chemical controls, many also practice cultural control to reduce the number of required chemical treatments.

The use of chemical control varies widely across the Cotton Belt. Some growers routinely apply insecticides to prevent the buildup of destructive boll weevil population densities. Chemical treatment is initiated annually on a scheduled date and continues regularly until the crop is no longer vulnerable to economic damage.

A high percentage of cotton acreage is scouted by professional crop consultants, growers, or government personnel for boll weevil populations and pest damage as a guide for the use of insecticides and other appropriate actions. Some of these scouting programs are government sponsored, usually by the Cooperative Extension Service, while others are private enterprises. After field counts are made, farmers, County Extension Agents, privately employed scouts, or independent pest management consultants make decisions as to what action to take (USDA, 1983a).

In 1987, the boll weevil infestation was more severe nationwide than in the previous year. In most Cotton Belt States, boll weevil damage caused more reduction in yield than any other cotton pest (table 2-6).

Approximately 52 percent of the harvested acreage was infested with boll weevils, and almost 38 percent of all harvested acreage surpassed treatment thresholds for boll weevil control (King et al., 1988).

Much of the acreage harvested in 1987 that was not infested with the boll weevil was located in California (1.1 million acres) and Texas (2 million acres). In some areas, such as the northern limits of the Cotton Belt, infestations were minor and few growers felt that treatments were necessary to protect the crop. In many cases, insecticides applied to control other cotton pests probably had some effect in suppressing boll weevil populations.

Estimates of the number of acres treated annually for the boll weevil vary because of changes in pest populations. National averages also fail to accurately convey the intensity of treatment undertaken in some areas of the Cotton Belt. From 1981 to 1984, commercial growers applied treatments to boll weevils to more than 75 percent of the cotton acreage in western Arizona, southern Texas, Mississippi, Arkansas, Georgia, northwest Louisiana, and Florida (Suguiyama and Osteen, 1988).

The number of annual insecticide applications for boll weevil control also varies (table 2-7). While the national average in 1987 was 2.6 treatments per treated acre, California (less than 0.01 treatments/acre) and Tennessee (0.4 treatments/acre) averaged a much lower number of treatments during this period. In contrast, the southeastern States averaged much higher numbers of applications per harvested acre: Mississippi Hill averaged 8.6 treatments per treated acre, and northern Alabama averaged 7.7 treatments per treated acre. It should be noted that treatments for secondary pests probably had some suppressive effects on the boll weevil in these areas.

In recent years, the quantity of insecticide (in pounds of active ingredient) applied to cotton has declined (Cooke and Parvin, 1983; Suguiyama and Osteen, 1988). Many pest management experts attribute this decline to the availability of more effective, although more costly, synthetic pyrethroid pesticides (Cooke and Parvin, 1983; NRC, 1981). Other entomologists believe that the reduction in pesticide use is a result of the implementation of cotton pest management systems that incorporate many nonchemical controls (NRC, 1981; Frisbie et al., 1983). These alternative management systems include the following:

- The use of short-season cultural methods in Texas (Frisbie et al., 1983)

- Community-wide management of cotton pests in Arkansas (Phillips et al., 1980)

**Table 2-6. Comparative Loss of Revenue and Costs of Control for the Boll Weevil and Other Cotton Pests in 1987**

| Region | Loss of revenue per acre (dollars) | | | Average cost of treatment per acre (dollars) | | |
|---|---|---|---|---|---|---|
| | Total (all pests) | Boll weevil | Certain other pests[a] | Total (all pests) | Boll weevil | Certain other pests[a] |
| **Southeast:** | | | | | | |
| Coastal— | | | | | | |
| Northern Alabama | 46.67 | 26.26 | 14.83 (boll/budworms) | 44.47 | 15.02 | 26.25 (boll/budworms) |
| Central and Southern Alabama | 43.27 | 25.41 | 12.07 (boll/budworms) | 46.91 | 15.33 | 19.10 (boll/budworms) |
| Florida | 63.83 | 31.42 | 31.75 (boll/budworms) | 82.98 | 20.00 | 61.77 (boll/budworms) |
| Georgia | 36.56 | 27.03 | 8.32 (boll/budworms) | 113.25 | 62.25 | 41.85 (boll/budworms) |
| North Carolina | 3.72 | 0.00 | 2.77 (boll/budworms) | 25.45 | 0.00 | 18.90 (boll/budworms) |
| South Carolina | 6.43 | 0.00 | 5.71 (boll/budworms) | 22.74 | <0.30 | 18.90 (boll/budworms) |
| Virginia | 7.30 | 0.00 | 7.16 (boll/budworms) | 11.89 | 0.00 | 11.00 (boll/budworms) |
| Delta— | | | | | | |
| Arkansas | 27.45 | 22.06 | 4.81 (boll/budworms) | 48.10 | 32.52 | 8.00 (boll/budworms) |
| Missouri | 19.08 | 1.90 | 9.49 (boll/budworms) | 10.85 | 1.20 | 4.50 (boll/budworms) |
| Louisiana | 45.23 | 27.81 | 12.90 (boll/budworms) | 54.79 | 19.38 | 28.50 (boll/budworms) |
| Mississippi Delta | 53.18 | 17.41 | 24.28 (boll/budworms) | 49.95 | 11.98 | 28.27 (boll/budworms) |

**Table 2-6. Comparative Loss of Revenue and Costs of Control for the Boll Weevil and Other Cotton Pests in 1987 (continued)**

| Region | Loss of revenue per acre (dollars) | | | Average cost of treatment per acre (dollars) | | |
|---|---|---|---|---|---|---|
| | Total (all pests) | Boll weevil | Certain other pests[a] | Total (all pests) | Boll weevil | Certain other pests[a] |
| Mississippi Hill | 43.73 | 26.15 | 12.39 (boll/budworms) | 45.06 | 17.20 | 21.88 (boll/budworms) |
| Tennessee | 10.24 | 0.68 | 8.96 (boll/budworms) | 6.54 | 1.60 | 3.50 (boll/budworms) |
| **South Central:** | | | | | | |
| Oklahoma | 8.33 | 2.99 | 4.72 (boll/budworms) | 17.10 | 3.32 | 11.55 (boll/budworms) |
| Texas 1 (High Plains) | 1.15 | 0.22 | 0.29 (fleahoppers) | 4.27 | 0.51 | 0.45 (fleahoppers) |
| Texas 2 (High Plains) | 16.21 | 0.00 | 10.80 (fleahoppers) | 10.18 | <0.55 | 1.38 (fleahoppers) |
| Texas 3 (Rolling Plains) | 8.51 | 6.70 | 1.54 (boll/budworms) | 10.17 | 5.61 | 2.85 (boll/budworms) |
| Texas 4 (Rolling Plains) | 1.38 | 0.01 | 1.05 (boll/budworms) | 10.44 | <0.42 | 4.00 (boll/budworms) |
| Texas 5 & 9 (Blacklands) | 38.53 | 12.63 | 12.63 (boll/budworms) | 32.73 | 15.50 | 12.00 (boll/budworms) |
| Texas 6 (Trans Pecos) | 21.78 | 0.00 | 13.50 (boll/budworms) | 20.30 | <0.60 | 13.50 (boll/budworms) |
| Texas 7 (Upper Concho) | 19.94 | 6.38 | 6.84 (fleahoppers) | 19.82 | 7.70 | 9.00 (boll/budworms) |
| Texas 8 (Blacklands) | 35.57 | 13.37 | 11.14 (fleahoppers) | 30.92 | 6.00 | 7.00 (fleahoppers) |
| Texas 10 (Blacklands) | 3.80 | 0.19 | 3.29 (boll/budworms) | 10.95 | <0.46 | 9.10 (boll/budworms) |

**Table 2-6. Comparative Loss of Revenue and Costs of Control for the Boll Weevil and Other Cotton Pests in 1987 (continued)**

| Region | Loss of revenue per acre (dollars) | | | Average cost of treatment per acre (dollars) | | |
|---|---|---|---|---|---|---|
| | Total (all pests) | Boll weevil | Certain other pests[a] | Total (all pests) | Boll weevil | Certain other pests[a] |
| Texas 11 (Central River Bottom) | 29.76 | 3.50 | 15.74 (fleahoppers) | 9.19 | 1.20 | 1.98 (fleahoppers) |
| Texas 12 (Lower Rio Grande) | 50.44 | 36.60 | 11.15 (boll/budworms) | 85.79 | 47.25 | 34.00 (boll/budworms) |
| Texas 13 (Winter Garden) | 178.82 | 46.96 | 106.44 (boll/budworms) | 135.27 | 31.35 | 85.20 (boll/budworms) |
| Texas 14 (Upper & Lower Coast) | 22.67 | 10.26 | 6.82 (fleahoppers) | 75.04 | 21.00 | 3.60 (fleahoppers) |
| Kansas | NA | NA | NA | NA | NA | NA |
| **Southwest:** | | | | | | |
| California | 24.29 | 0.00 | 15.30 (minor pests) | 9.44 | 0.00 | 1.20 (minor pests) |
| Arizona | 27.84 | 0.68 | 17.48 (pink bollworm) | 120.50 | 11.07 | 52.20 (pink bollworm)[b] |
| New Mexico | 12.84 | 0.00 | 3.23 (thrips) | 4.74 | 0.00 | 0.70 (thrips) |

[a] The pest cited caused the most extensive damage among all other cotton pests.
[b] Other pests that caused significant damage in Arizona in 1987 include *Heliothis* sp., Lygus bugs, and spider mites.

Note: NA = Not available.

Source: Adapted from King et al., 1988.

## Table 2-7. Estimated Damage to Cotton in the United States by the Boll Weevil With Consequent Cost of Control and Yield Loss in 1987

| Program area | Acres requiring treatment | Average number of treatments/ treated acre | Average cost/ acre for treatment (dollars) | Average loss of revenue/acre due to yield reduction (dollars) |
|---|---|---|---|---|
| **Southeast**: | | | | |
| Coastal— | | | | |
| Northern Alabama | 200,000 | 7.7 | 15.02 | 26.26 |
| Central & Southern Alabama[a] | 152,000 | 7.3 | 15.33 | 25.41 |
| Florida[a] | 25,050 | 4.0 | 20.00 | 31.42 |
| Georgia[a] | 255,000 | 16.6 | 62.25 | 27.03 |
| North Carolina | 0 | 0 | 0.00 | 0.00 |
| South Carolina | 50 | 0 | 0.00 | 0.00 |
| Virginia | 0 | 0 | 0.00 | 0.00 |
| Delta— | | | | |
| Arkansas | 550,000 | 7.1 | 32.52 | 22.06 |
| Missouri | 18,000 | 0.3 | 1.20 | 1.90 |
| Louisiana | 585,272 | 6.8 | 19.38 | 27.81 |
| Mississippi Delta | 606,657 | 5.1 | 11.99 | 17.41 |
| Mississippi Hill | 227,708 | 8.6 | 17.20 | 26.15 |
| Tennessee | 35,998 | 0.4 | 1.60 | 0.68 |
| **South Central**: | | | | |
| Oklahoma | 95,000 | 7.1 | 32.52 | 2.99 |
| Texas 1 (High Plains) | 10,000 | 0.1 | 0.51 | 0.22 |
| Texas 2 (High Plains) | 15,000 | 0 | 0.00 | 0.00 |
| Texas 3 (Rolling Plains) | 250,000 | 1.1 | 5.61 | 6.70 |
| Texas 4 (Rolling Plains) | 5,000 | 0 | 0.00 | 0.01 |
| Texas 5 & 9 (Blacklands) | 20,000 | 3.1 | 15.50 | 12.63 |
| Texas 6 (Trans Pecos) | 1,500 | 0 | 0.00 | 0.00 |
| Texas 7 (Upper Concho) | 100,000 | 1.4 | 7.7 | 6.38 |
| Texas 8 (Blacklands) | 15,000 | 1.5 | 6.00 | 13.37 |
| Texas 10 (Blacklands) | 3,870 | 0 | 0.00 | 0.19 |
| Texas 11 (C. River Bottom) | 8,600 | 0.3 | 1.20 | 3.50 |
| Texas 12 (Lower Rio Grande) | 320,000 | 7.0 | 47.25 | 36.60 |
| Texas 13 (Winter Garden) | 37,000 | 6.6 | 31.35 | 46.96 |
| Texas 14 (Upper & Lower Coast) | 171,396 | 4.2 | 21.00 | 10.26 |
| **Southwest**: | | | | |
| California | 0 | 0.0 | 0.00 | 0.00 |
| Arizona[b] | 50,000 | 1.3 | 11.70 | 0.68 |
| New Mexico | 0 | 0.0 | 0.00 | 0.00 |
| **National** | 3,758,401 | 2.6 | 9.62 | 9.45 |

[a] Includes treatments applied by the Southeast Boll Weevil Eradication Program.
[b] Includes treatments applied by the Southwest Boll Weevil Eradication Program.

Source: Adapted from King et al., 1988.

- Preventive cultural controls, including crop rotation and timely stalk destruction in the Southeast

- Fall diapause treatment in the St. Lawrence Valley of west Texas (Neeb and Cole, 1973)

The no action alternative may result in reinfestation of all currently eradicated acreage, as well as the infestation of other weevil-free acreage. Additionally, this alternative may result in the net loss of all funds previously allocated for eradication, and the reversion to current control practices in currently eradicated acreage, as well as an increase in production costs in these areas.

### Alternative 2—Beltwide Eradication of the Boll Weevil

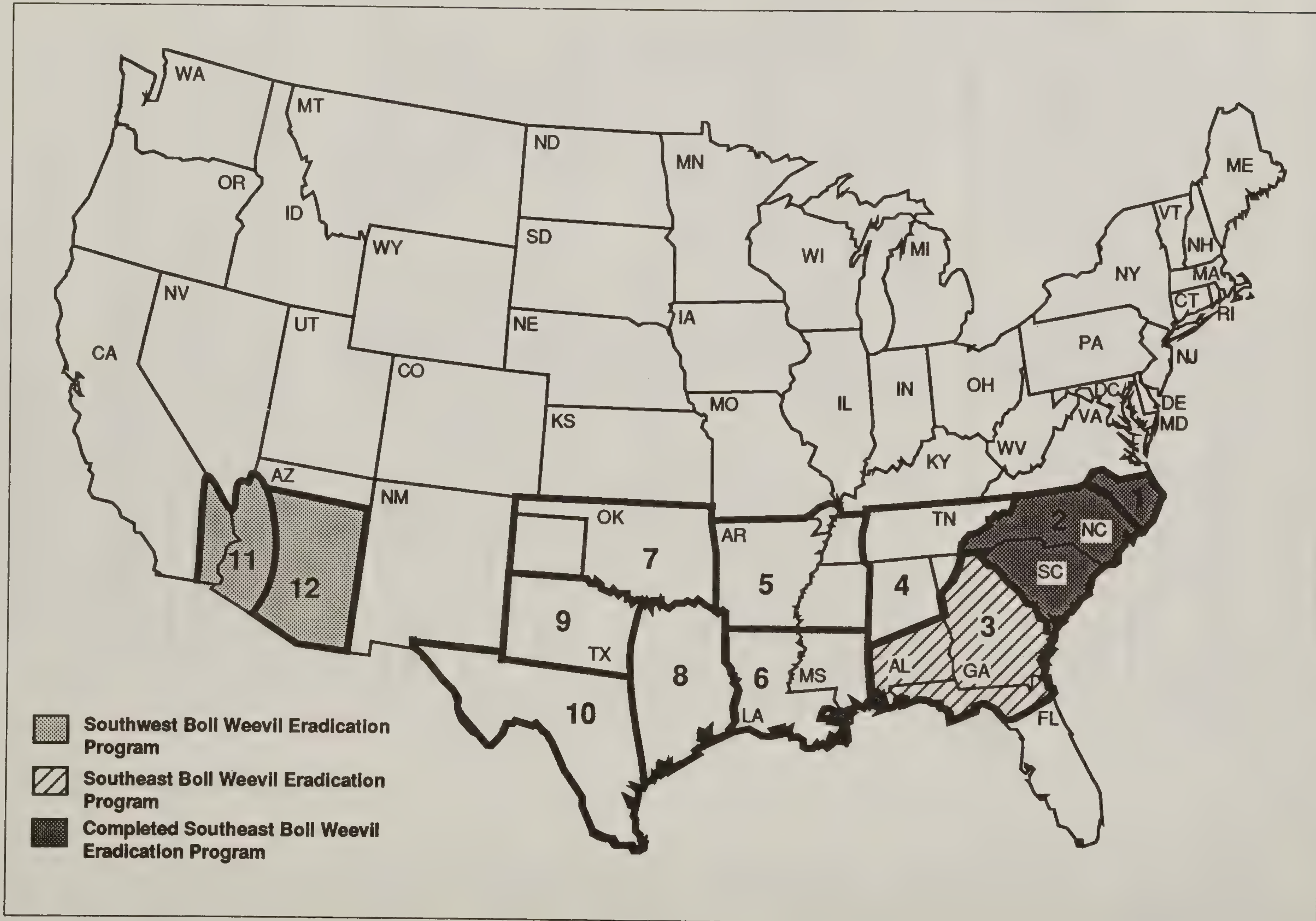
***Full Federal Involvement.*** Under this eradication alternative, program cooperators would seek to eradicate the boll weevil from cotton-producing areas of the United States. For the purposes of the program, the goal of eradication will be considered to be met when boll weevil populations are reduced to undetectable levels across the Cotton Belt. To achieve this goal, APHIS would conduct sequential eradication programs in conjunction with cooperating States, growers, and other Federal agencies; maintain buffer zones between eradicated areas and infested regions; and encourage the use of cultural control methods. This will enhance the growers' ability to use beneficial insects for controlling secondary pests and will reduce the need for chemical treatments (Carlson and Suguiyama, 1985).

Although all cotton acreage in the Cotton Belt eventually would be included, the eradication program would move across the Cotton Belt in manageable increments. Within each increment, only infested acres would be treated. The area encompassed by a management increment would not necessarily be bounded by State lines. Rather, the size of a management unit would be determined by operational constraints, including availability of funding and personnel, equipment needs, and natural breaks between contiguous cotton areas. Figure 2-1 illustrates proposed management increments for implementation of the eradication alternative.

This cooperative program would use an integrated control approach in choosing control methods. The selection of a particular control method or combination of methods on an individual site would take into consideration several factors, including variations in weevil biology, availability of overwintering sites, environmental concerns, weather patterns, and crop production requirements. The integrated control approach used in the program would include the following four components:

1. Field mapping and systematic pheromone trapping to detect and delimit boll weevil populations

Figure 2-1. Proposed Management Increments for Implementation of the Eradication Alternative



2. Mandatory participation by cotton growers following a positive referendum

3. Judicious use of available control measures in response to existing pest conditions and environmental concerns

4. Limitation of control application to infested acreage

Because the goal of this program would be eradication and not management of a pest population, the proposed integrated control approach is not an integrated pest management (IPM) program. However, like an IPM program, the proposed integrated control approach would evaluate and consolidate all available control techniques into a unified control program to achieve program goals and to minimize adverse effects on the environment.

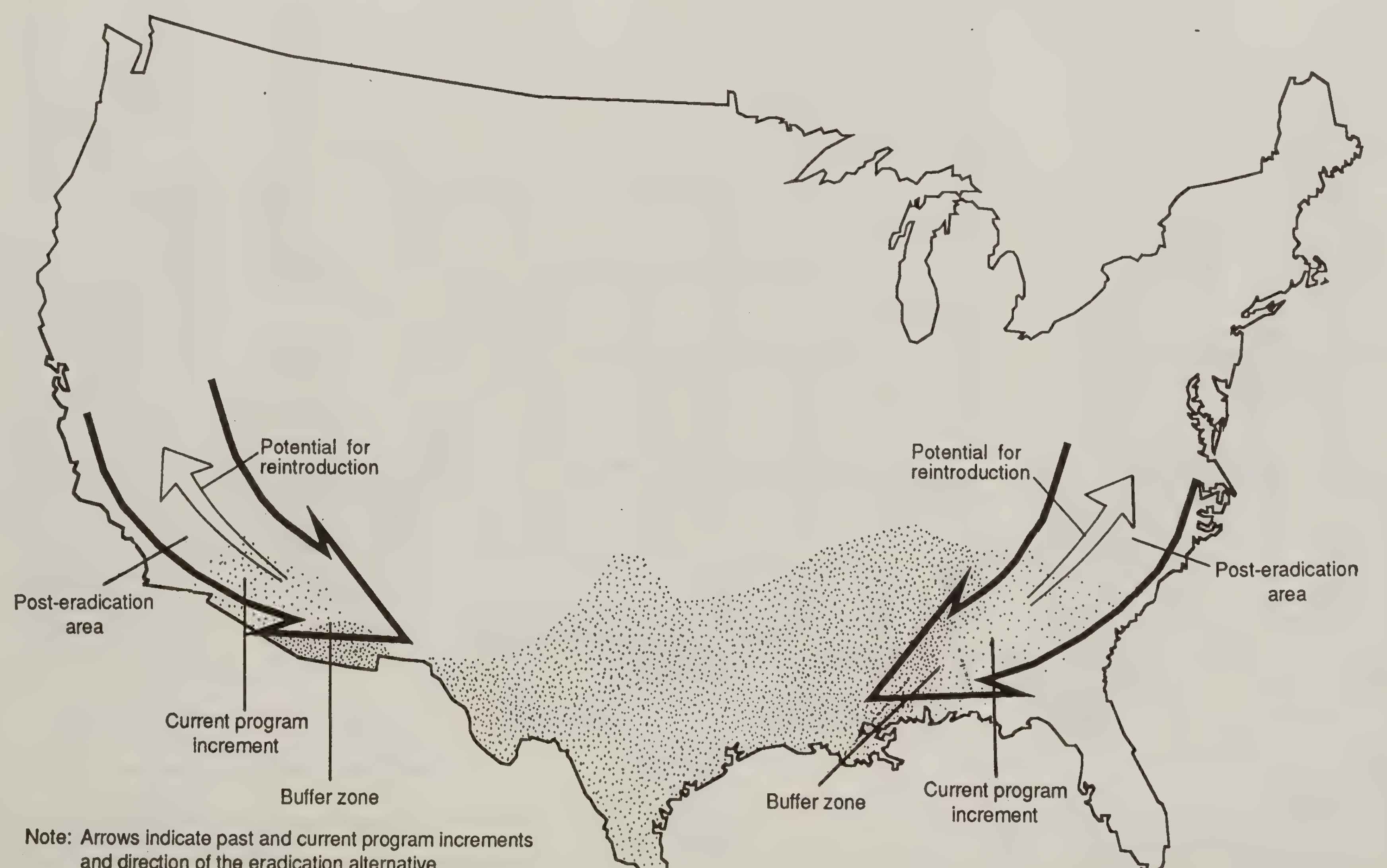
The eradication program has three phases: eradication, confirmation, and post-eradication. The eradication phase consists of the current program increment and the buffer zone. As the eradication program moves from current post-eradication zones into the current increment (the active eradication zone), the leading edge of the increment becomes the buffer between the active eradication zone and the adjacent infested acreage. The confirmation phase takes place when 99 percent of the increment's acreage is weevil-free. Eradication activity during this phase is concentrated on the remaining "hot spots" where weevils are trapped. After the weevils have been eradicated, post-eradication activities are conducted to prevent reinfestation. Figure 2-2 illustrates the components and movement of the eradication program through the Cotton Belt. Each phase is explained in greater detail in the following sections.

Before any eradication treatments are conducted in a given area, all cotton acreage would be identified, mapped, and surveyed and pheromone traps would be placed around cotton fields at a density of approximately one trap per 50 to 75 acres. Traps would be installed in the spring, near typical overwintering sites, and serviced for 2 to 3 months during the period of peak weevil emergence.

Alternatively, traps could be placed in late summer and serviced for several weeks prior to the onset of diapause. These surveys would indicate large areas within the overall program increment that are likely to support significant populations of overwintered weevils each season.

Once these high-risk areas had been identified, planning would begin for a modified series of fall diapause treatments. Depending on crop phenology, weevil density, and weather, cotton fields in high-risk areas would receive three to five treatments the first fall. The following spring, traps would be reinstalled (one trap per acre) around all cotton fields. Fields with populations emerging from diapause would receive two insecticide treatments 7 days apart. Treatments would continue on

Figure 2-2. Components and Movement of the Eradication Alternative




Note: Arrows indicate past and current program increments and direction of the eradication alternative.
Dot density indicates relative weevil population (that is, more dots equal more weevils).

a weekly interval until thresholds are no longer exceeded. Chemicals available for use include malathion, azinphos-methyl, methyl parathion, and diflubenzuron.

During the first full season of the program, the average number and frequency of insecticide applications would vary across the Cotton Belt. In most infested areas, generally six to eight insecticide applications would be required over the growing season. In a small percentage of heavily infested fields, as many as 25 treatments may be required during the first year of the program.

During the second full season of the program, a significant reduction in the number of chemical treatments and the number of fields requiring chemical treatments would be expected. Based on recent experience in the Southeast and Southwest, most future increments could expect a 40- to 60-percent reduction in the amount of boll weevil insecticide used in the second season of the program. Control activity, however, may intensify in small localized areas because of isolated pockets of heavy infestation.

Throughout the program, growers would be encouraged to implement cultural control measures (short-season techniques, stalk destruction, crop rotation, and production limitation) to reduce the need for chemical treatment. For example, there may be areas inaccessible to chemical treatment or areas where chemical treatment is undesirable. Some States prohibit planting cotton in such areas. Where those prohibitions do not exist, it may be necessary to use mass trapping, sterile boll weevils, or even to plow under the infested crop pursuant to State authority. (Throughout the program, environmental resources, such as water, soil, and vegetation, will be monitored.)

The eradication phase is considered complete when spring trapping indicates 99 percent of the program acreage is free of infestation. The next phase, confirmation, concentrates on the remaining infested acres and lasts until boll weevil populations are at an undetectable level (i.e., no weevils are trapped). Post-eradication will continue until the risk of reinfestation becomes insignificant and will include detection, trapping, and response to any weevils captured.

In most program areas, boll weevil populations would be reduced to undetectable levels in an average of 2.5 years, with an additional year of moderate-density trapping to confirm eradication. An estimated 20 years would be required to fully implement the program in the remaining infested States in the Cotton Belt. (Fig. 2-1 illustrates proposed increments for implementation of the eradication alternative. The proposed sequencing of the implementation and the factors that may influence the sequence of the increments are discussed in chapter 4.) The duration of the program in any given area would depend on seasonal weather variations (harsh vs. mild winters), level of infestation, availability of overwintering sites, the distribution of cotton fields (contiguous vs. isolated), and the availability of appropriate funding.

Full Federal participation in an eradication program is expected to involve 30 percent Federal funding of all program costs. Program cooperators would determine the integrated control strategy used by the program and how to maintain and monitor any buffer zones. APHIS would assist in monitoring eradicated areas to guard against reintroduction of the weevil. Under this alternative, APHIS would also participate in the selection and acquisition of insecticides and would be involved with the supervision of any chemical treatment required for boll weevil control.

***Limited Federal Involvement.*** Under this eradication alternative, APHIS would participate in a cooperative program to eliminate the boll weevil from cotton-producing regions in the United States. The goal of this program would be considered to be met when boll weevil populations are reduced to undetectable levels across the Cotton Belt. APHIS would support regional efforts to maintain buffer zones between eradicated areas and infested regions and would encourage the use of cultural control practices to protect beneficial insects and reduce the need for chemical treatment.

Under this alternative, APHIS participation would be limited to the following four program components:

1. Field mapping and systematic pheromone trapping to detect and delimit boll weevil populations

2. Development of recommendations for integrated control programs

3. Supervision of a post-eradication surveillance program

4. Environmental monitoring

Under this eradication alternative, grower representatives and/or States would make the final decision regarding control methodology, and APHIS would neither acquire nor supervise the application of insecticides.

Generally, control activities would involve continuous reduction in treated acreage over time. The program would proceed across the Cotton Belt in systematic increments. With each program increment, all cotton fields would be trap-surveyed and only infested fields would be treated. Eradicated areas would continue to be trap-surveyed to guard against reintroduction. The beltwide eradication effort would be expected to last approximately 20 years.

Limited Federal participation in an eradication program could involve 30 percent Federal funding (applied to nonchemical program costs), State and/or grower determination of the integrated control strategy for all fields, and APHIS supervision of all surveillance activities. APHIS

would not be responsible for the selection, acquisition, or supervision of application of any chemicals required for boll weevil control.

### Alternative 3—Beltwide Suppression of the Boll Weevil

***Full Federal Involvement.*** Under this suppression alternative, the cooperative program would seek to reduce and maintain boll weevil populations below levels that would be expected to result in significant economic loss. To achieve this primary goal, APHIS would conduct coordinated suppression programs in conjunction with cooperating States, growers, and other Federal agencies.

All cotton acreage within a particular program increment in the Cotton Belt would be included in the suppression effort, although only infested acreage would be treated in an effort to prevent economic crop loss. The economic threshold is that pest population level at the point at which the crop damage cost is greater than the cost of pest control. The economic threshold does not represent the pest population level that results in some damage but rather some higher level that, if left untreated, would result in economically significant boll loss.

Although a suppression program could theoretically be implemented throughout the Cotton Belt in a single season, practically this would be impossible because of the enormous manpower and equipment needs. Therefore, a suppression program would be incrementally implemented across the Cotton Belt. Program increments would correspond roughly to the increments proposed for the eradication alternative (fig. 2-3), although additional increments would be necessary to include currently uninfested areas.

As with eradication, the selection of particular control methods to be incorporated in the suppression program would be expected to vary across the Cotton Belt. The choice would depend on variations in weevil biology, availability of overwintering sites, weather patterns, and crop production requirements. This suppression program encourages the use of cultural control methods and attempts to conserve beneficial insect populations by proper timing and limited use of chemical controls. The cooperative program's integrated control approach would include the following four components:

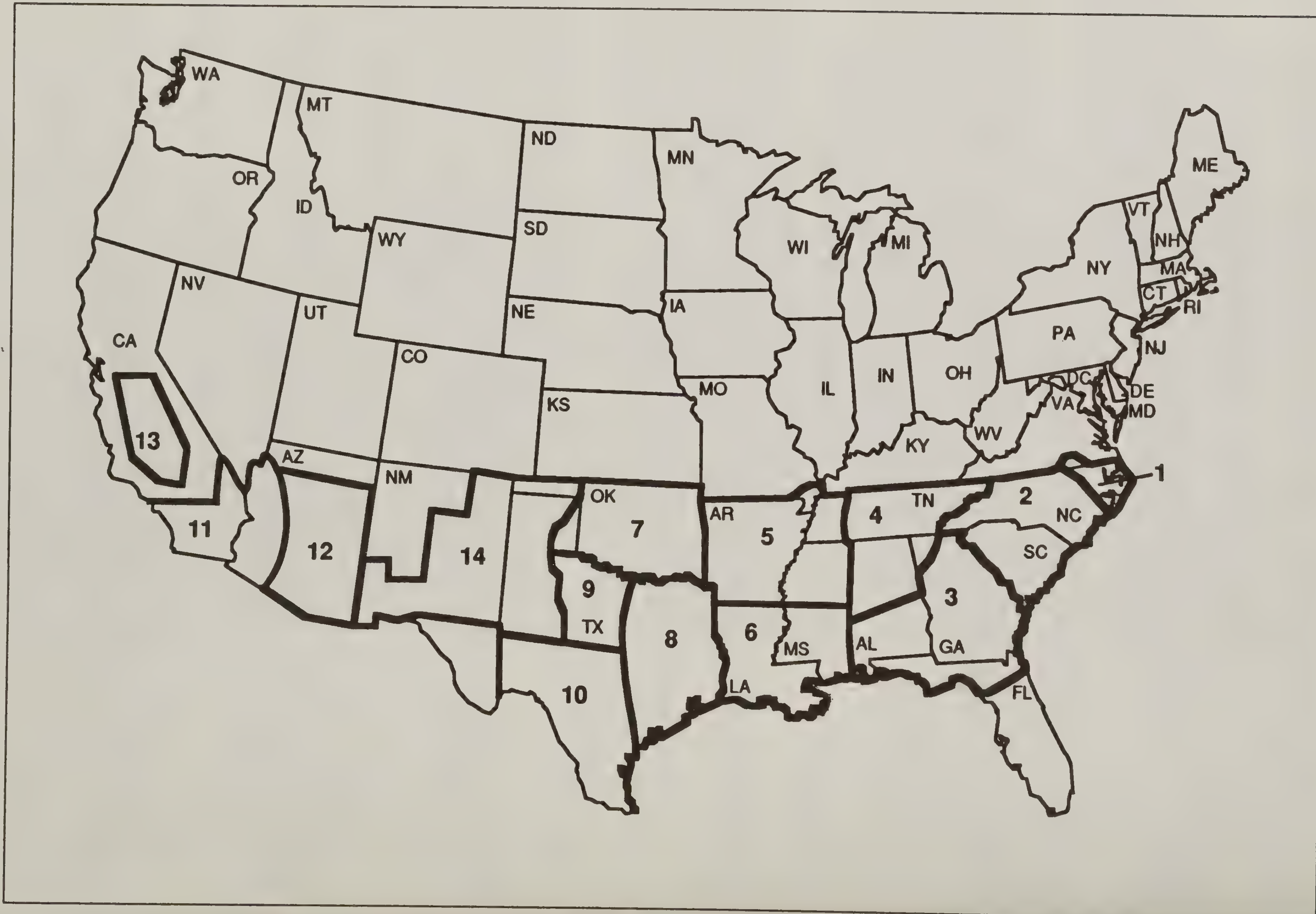
1. Field mapping and systematic pheromone trapping to detect and delimit boll weevil populations

2. Mandatory participation by cotton growers following a positive referendum

3. Judicious use of available control measures in response to existing pest conditions and environmental concerns

4. Limitation of control application to infested acreage

Figure 2-3. Proposed Management Increments for Implementation of the Suppression Alternative



Chemical control would be an important component in suppression programs in most areas. Because chemical control is the most expeditious method for suppressing high-density boll weevil populations, some areas would be dependent primarily on insecticide treatments. Proper timing of these applications can improve the effectiveness of the treatment, as well as conserve the beneficial insect population that may be critical in the control of other cotton pests.

Weevil populations are effectively suppressed in some areas by climatic conditions, especially harsh winters such as those frequently encountered in Tennessee, Missouri, and Texas. Cotton in these areas usually requires few if any chemical treatments for boll weevil control. Long, cold winters, like those that typically occur in the Texas High Plains, are particularly effective in suppressing boll weevil populations. In other areas, early season (pinhead-square), midseason, and diapause treatments may all be required to reduce populations below the economic threshold.

In this suppression program alternative, it is possible that 10 to 12 or more pinhead-square and midseason treatments per year may be required for heavily infested acres. Many fields, however, would require only one or two treatments late in the summer, followed by several carefully timed fall diapause treatments. Like the eradication alternative, a number of fields would require no treatment at all.

In most areas of the Cotton Belt, an average of three to five diapause treatments per field per year would be adequate to significantly reduce overwintering populations. This fall reduction may result in boll weevil populations the following spring that are well below the economic threshold. In areas having heavy, localized infestations, approximately 10 diapause treatments per field per year may be required to significantly suppress the population. In all cases, chemical treatments would be threshold dependent—that is, only those fields requiring treatment would be treated.

Although the frequency of applications of insecticides in a suppression program would normally be less than during the initial phases of an eradication program, much of the acreage to be treated could require repeated applications every season for an indefinite period. Fields that require treatments to protect the crop would receive repeated early and midseason treatments. Diapause treatments would normally be timed for maximum effect on the diapause population. Throughout the program, growers would be encouraged to implement cultural control methods to reduce the need for chemical treatments. Manipulation of planting and harvesting dates, use of short-season cotton varieties where feasible, and postharvest stalk destruction have all been shown to be valuable in suppressing boll weevil populations in at least some areas of the Cotton Belt.

Other nonchemical methods suggested for use in a suppression program include sterile weevil release, production limitations, and biological controls. Sterile insect release has not been proven effective in suppressing boll weevil populations at high population densities. However, sterile weevil release may eventually be effective in suppressing low-density populations in sensitive areas where chemical treatment is undesirable. Limiting cotton production in certain areas is not considered to be cost-effective in a suppression program. The benefits accrued from production limitations may be too small to justify the expense of the subsidy payments. Biological controls and other methods mentioned above would be required for sensitive sites or sites where chemical treatment is undesirable.

Under the suppression alternative, mandatory grower participation would be required, and APHIS would assume a reasonable portion of the costs of control. The program would have no anticipated completion date. There would be no projected end for APHIS's involvement.

***Limited Federal Involvement.*** Under this suppression alternative, the cooperative program would seek to reduce and maintain boll weevil populations below levels that would be expected to result in significant economic crop loss. To achieve this primary goal, APHIS would conduct coordinated suppression programs in conjunction with cooperating States, growers, and other Federal agencies to demonstrate the effectiveness of the suppression technology.

Beltwide suppression with limited Federal involvement is limited only in terms of duration. All elements of the alternative will be identical with full Federal involvement except that APHIS' involvement would end after 3 years in each geographic area. The objective of this alternative is to demonstrate the effectiveness of the technology and to develop cooperator expertise. After successfully completing that technology transfer, APHIS would move to the next geographic area, leaving the cooperators to operate the program. This suppression alternative has no termination date, but APHIS' involvement in each geographic area would be restricted to 3 years per increment.

## Alternatives Eliminated From Detailed Study

Three alternatives recommended during scoping were eliminated from detailed study: the use of nonchemical control only, IPM, and direct subsidies to growers. These alternatives are unable to suppress or eliminate boll weevil populations entirely. Further discussion of these methods is found below.

### Nonchemical Control Only

A recommendation put forth during the scoping process was that APHIS consider implementing a control program that does not include the use of chemical insecticides. Specifically, this program would call for complete dependence on nonchemical control methods, including the establishment of cotton-free zones, the use of cultural control

methods, the release of sterile insects, and the use of physical control through mass trapping.

Eradication or suppression of the boll weevil throughout its U.S. range is not presently considered technically feasible without some use of chemical insecticides. Chemical control is considered the only active control method that is consistently efficacious in rapidly suppressing or eliminating high-density populations of boll weevils. High and damaging populations can generally be reduced within hours and thus provide immediate protection of the crop (Knipling, 1979).

The benefits of nonchemical controls are varied and unpredictable, and for this reason, many growers are reluctant to depend entirely on these practices. In addition, the uncertainties associated with commodity prices and weather may force a grower to choose to abandon cotton before the benefits of nonchemical controls are realized.

Areawide bans on cotton production historically have been suggested as being effective in eliminating the boll weevil at all population densities (Davich, 1988; Helms, 1977); however, proposals to ban cotton production to eliminate the host material of the boll weevil have not received popular support, and bans of this type, without compensation to growers and related industries, are considered economically unreasonable.

Purchase and destruction of infested cotton acreage would be prohibitively expensive on a large scale and would involve numerous legal impediments. This approach, therefore, is not feasible in a large areawide control program.

Other nonchemical control methods are limited in effectiveness to low population densities, and they cannot be used alone to suppress or eliminate the boll weevil from heavily infested fields. These methods include mass trapping and the release of sterile insects. In addition, the sterile insect technique is not available for large-scale use at this time. The use of this technique on a beltwide basis would require the construction and operation of a large-scale sterile insect production facility. An estimated 7 years and approximately $10 million would be required before adequate supplies of sterile insects would be available for release.

Cultural control methods provide some degree of population reduction, but they cannot be used alone to effectively suppress or eliminate a population. These methods are preventive and do not provide direct or immediate crop protection (Knipling, 1979). In many cases, the suppression provided by cultural techniques is inadequate, and chemical insecticides are still required.

Many current insect management schemes do not seek to eliminate chemical treatment, but rather seek to reduce the number of required treatments by implementing nonchemical control methods whenever

possible (Bottrell and Adkisson, 1977). Elimination of chemical control methods would not accomplish the goals of beltwide eradication or even suppression; therefore, this program alternative has been eliminated from further analysis.

### Integrated Pest Management

Integrated pest management (IPM) is an approach to cotton pest management that uses several control methods, including cultural practices, the selective use of pesticides, field surveys, the use and protection of beneficial insects, and diapausing boll weevil control (Alabama Cooperative Extension Service, 1990). One hundred percent participation by the grower community is essential to the success of an IPM program.

The goal of IPM programs is to suppress insect populations below damaging economic levels, not reduce them to zero. Insecticides are not used until the cost of the damage the insect causes exceeds the cost of the insecticide and application necessary to control it. Intense field scouting is important in determining when insect populations reach the economic threshold. Economic thresholds vary depending on several factors, including weather conditions (temperature and rainfall influence the plant's tolerance to insect damage), the presence of beneficial insects (a high or increasing number can increase the threshold level), the field's treatment history, the field's yield potential (the economic return for the same treatment may vary from field to field), and the combination of pests present (several pests, although each may be below economic thresholds, can add up to damaging levels) (Alabama Cooperative Extension Service, undated).

When boll weevils are present, a true IPM strategy for suppressing cotton insect pests is infeasible. The relatively warm winters, the availability of overwintering sites, and the lack of known biological and other effective nonchemical controls enable the boll weevil to be an economic pest for the entire growing season, one that requires the continued use of broad-spectrum insecticides. This continued use of broad-spectrum insecticides also depletes populations of beneficial insects and necessitates the use of other insecticides to control the remaining cotton insect pests. However, an integrated control strategy is similar to IPM and can be used with some success by individual growers. A single treatment at the early spring pinhead-square stage (late May or early June) timed to kill overwintered weevils before they lay eggs can be very effective in controlling boll weevils. By avoiding multiple treatments, beneficial insects have an opportunity to reestablish themselves, thereby helping to control other pests. Then no weevils should appear until early July, and four or five treatments should result in subeconomic levels of weevil infestation for the rest of the season, according to a personal communication with Dr. Ron Smith (1990). Beltwide suppression or eradication of the boll weevil, however, is impossible unless individual growers coordinate their methods of boll weevil control. A beltwide suppression or eradication program

would use an integrated control approach to boll weevil control, thus incorporating many IPM principles.

### Direct Subsidies to Growers

Direct subsidies to cotton growers for control of the boll weevil or as compensation for crop loss is not considered a reasonable alternative for boll weevil control. Direct subsidies offer no long-term solution to the boll weevil problem and do not reduce the environmental impacts that may be associated with insecticide application.

The costs associated with a new agricultural subsidy may not be reasonable under Federal budgetary constraints. The analysis of the probability of congressional approval of a new subsidy system is outside the scope of this EIS.

## The Preferred Alternative: Beltwide Eradication (Full Federal Involvement)

The Council on Environmental Quality regulations for implementing the procedural provisions of the National Environmental Policy Act (40 CFR 1502.14(e)) require a Federal agency to include its preferred alternative in the draft and final EIS of a proposed action, provided no other law prohibits the expression of such a preference. APHIS, after much consideration, has determined that beltwide eradication of the boll weevil (full Federal involvement) using integrated control techniques is the preferred alternative.

Selection of the preferred alternative was based on a complete and comparative evaluation of program and control alternatives with respect to technological and practical efficacy, environmental effects, economics, mitigatory flexibility, and acceptability to the public. Criteria used were (1) risk to human health and nontarget species, (2) potential for environmental degradation, (3) Federal cost, (4) Federal personnel requirements, (5) potential grower acceptance, (6) program duration, (7) cumulative acreage actively controlled, and (8) potential to meet goals.

The alternatives were analyzed and compared with regard to both their short-term and long-term effects. APHIS has considerable experience with boll weevil eradication and has played a prominent role in the broader perspectives of classical boll weevil control and pest management in American agriculture in general. This experience provides a basis for informed selection.

The no action alternative is considered an unreasonable approach because it fails to solve the problems caused by weevil infestation. Many cotton producers effectively control the boll weevil. Frequently, however, an adjacent landowner is not as skilled or responsible in managing his or her crop and provides a breeding ground for the pest. The inaction of a few growers contributes to the continual reinfestation of nearly all cotton. If the problem is not approached from an areawide perspective, it will persist as long as cotton is grown, and the associated adverse impacts will be felt by producers, consumers, and the

environment. Furthermore, the no action alternative would result in the eventual infestation of nearly 5 million additional acres that are currently free of the weevil. The additional cost and environmental consequence of continual treatment on this acreage would be added to that already incurred in the 7 million acres that are currently infested.

The suppression alternative could provide some relief to the problem caused by boll weevil infestation. The two approaches to suppression, however, have inherent weaknesses. Under either approach, participating States would need to maintain an unending regulatory presence in the program area. If effective regulations were not continually enforced, it is possible that individual growers would become noncompliant. Such noncompliance may increase over time and potentially erode the benefits of areawide pest management. An areawide boll weevil management trial was conducted in Mississippi from 1978 to 1980. Immediately following this demonstration of new technology, many growers quickly reverted to traditional control practices, including the use of lower treatment thresholds and more toxic pesticides.

The total amount of insecticides required during several years of a suppression program exceeds the total amount of insecticide required to eradicate the weevil in a particular area. The additional insecticides required to control secondary pests due to the continued use of pesticides to control the boll weevil should also be considered when comparing the no action and suppression alternatives.

The long-term use of insecticides in the suppression alternative increases the potential for the weevil to develop resistance to these insecticides. The continuing potential of the weevil to inflict economic damage is an additional weakness of the suppression alternative.

Appropriate integration of control strategies in a systems approach—integrated control—affords the best combination of environmental protection and program efficacy. As implemented by APHIS, the selection of the preferred alternative would allow any of the proposed control alternatives to be selected singly or in combination for immediate and long-term boll weevil control, in direct support of, or leading to, eradication efforts. The selection of a particular control method or combination of methods under the preferred alternative would take into consideration several factors, including ecological factors (the impact on nontarget organisms and the environment), economic factors (the cost and cost effectiveness of various methods in both the short and long term), and sociological factors (the acceptability of various integrated methods to cooperators or the potential effects on land use).

### Criteria for Selecting the Preferred Alternative

The preferred alternative must not pose an unacceptable risk to the human environment and must be economically sound. In addition, the preferred alternative must be effective in achieving the program goal

within a reasonable period of time, must be technically and operationally feasible, and must be acceptable to cotton growers. A summary of the analyses of these factors is presented in table 2-8.

The analysis of the potential risks to human health and the environment is discussed in detail in chapter 4 and is summarized in table 2-4. In part, these risks will depend on the total amount of insecticides used under each alternative, as well as the intensity of treatment over the lifetime of the program (short-term vs. long-term impacts).

The eradication alternative has been judged to be technically and operationally feasible (USDA, 1981). Ultimate success of the program may be contingent on continuation of necessary funding from Federal or State governments, the passage of necessary regulations or laws through State legislative action, or successful achievement of the program goal in the early stages of the control program.

Implementation of the preferred alternative would take place in sequential increments. The size of an increment would be constrained primarily by budget, personnel, and the geographic orientation and nature of cotton fields. These constraints would directly affect the amount of time required to complete an eradication program or implement a suppression program in each increment.

Finally, the preferred alternative must be acceptable to growers. Because most States currently lack regulatory authority regarding grower participation in a beltwide control program, some revision of State statutes is required before States may participate in cooperative control programs. Legislative approval is contingent on the support of a majority of growers as indicated by referendum. States in which growers do not support the referendum will be unable to participate in the beltwide control program.

**Need for Flexibility**

The success of a boll weevil control program will depend on the ability of program managers to respond to varying conditions and boll weevil populations within each program increment. For this reason, no single strategy can effectively be used to achieve program goals in all areas. Weather conditions, degree of boll weevil infestation, and area-specific agricultural practices determine the applicability and effectiveness of particular control methods in particular areas of the Cotton Belt.

Individual cotton fields within each increment of the Cotton Belt vary and may require uniquely tailored control strategies. Factors that may be considered in the choice of control methods at the field level include degree of boll weevil infestation; field size; accessibility to treatment equipment; stage of cotton crop development; and proximity to overwintering sites, other fields, and environmentally sensitive areas. Therefore, season-long surveillance of all fields and timely treatment and response to infestation are critical components of successful control programs.

**Table 2-8. Evaluation Criteria for Selecting the Preferred Alternative**

| Criterion | No action | Eradication | | Suppression | |
|---|---|---|---|---|---|
| | | Full Federal involvement | Limited Federal involvement | Full Federal involvement | Limited Federal involvement |
| APHIS cost (millions of dollars) | 0 | 173 | 103 | 1,616[a] | 275 |
| Federal personnel requirements | Substantial reduction | Moderate increase | Moderate reduction | Substantial increase | Increase (3 yrs/increment) |
| Potential grower acceptance | Moderate/low | High | High | Low | Low |
| Program duration/increment | Not applicable | Limited (3.5 yrs.) | Limited (3.5 yrs.) | Indefinite | Limited (3 yrs/increment) |
| Program duration/Cotton Belt (years) | NA | 22 | 22 | Indefinite | 30 |
| Cumulative acreage (millions) controlled by programs | NA | 49 | 49 | 594[b] | 102 |
| Potential for alternative to meet goal | NA | High in limited geographic areas. High potential for success across Cotton Belt. | | High in broader geographic areas. Moderate potential for success across entire Cotton Belt. Program has no endpoint. | |
| Risk to human health | Potential for slight to significant risk of adverse health effects. Degree of risk dependent on choice of chemical. | Potential for slight to significant risk of adverse health effects. Degree of risk dependent on choice of chemical. Mitigation reduces risk to acceptable levels. | | Potential for slight to significant risk of adverse health effects. Degree of risk dependent on choice of chemical. Mitigation reduces risk to acceptable levels. Program has no endpoint. | |
| Risk to nontarget species | Potential for some slight to significant adverse effects on nontarget species. Degree of risk dependent on choice of chemical. | Potential for some slight to significant adverse effects on nontarget species. Degree of risk dependent on choice of chemicals. | | Potential for some slight to significant adverse effects on nontarget species. Degree of risk dependent on choice of chemical. Program has no endpoint. | |

Table 2-8. Evaluation Criteria for Selecting the Preferred Alternative (continued)

| Criterion | No action | Eradication | | Suppression | |
|---|---|---|---|---|---|
| | | Full Federal involvement | Limited Federal involvement | Full Federal involvement | Limited Federal involvement |
| Potential for environmental degradation | Greater potential for cumulative effects in the long term. | Negligible potential for cumulative effects in the long term. | | Greater potential for cumulative effects in the long term. Program has no endpoint. | |

[a] Although this suppression alternative would have no termination date, this is the anticipated APHIS cost for the first 30 years of the program.
[b] Although this suppression alternative would have no termination date, this is the cumulative acreage controlled for the first 30 years of the program.

The number of acres of cotton production varies annually and has ranged from almost 15 million acres to less than 8 million acres per year over the past 25 years (USDA, 1988). Fluctuations in boll weevil range and population levels also occur annually. These variations make it impossible to precisely predict or identify the number of acres likely to be treated in a future eradication or suppression program. For the sake of comparison, however, certain assumptions may be made.

For the purposes of this EIS, it will be assumed that all cotton acreage in the United States would be included in a suppression program. However, under an eradication program, only the cotton acreage infested with boll weevils would be subject to control. Before any control program is initiated, program cooperators would first map, trap, and survey all cotton acreage and would service those traps on a regular basis to identify fields requiring treatment.

## Operational Procedures and Mitigation Measures

A number of measures to increase the safety and reduce the potential impacts of a control program have been incorporated as operational procedures (table 2-1) and mitigation measures (table 2-2) for the alternatives being considered. The operational procedures are program operations that were developed as a part of the initial proposal for controlling the boll weevil and are required in all program activities receiving APHIS funding. The recommended mitigation measures are based on prior program experience and the analyses in the EIS. All required procedures and measures will be noted in the Record of Decision. APHIS will stipulate applicable operational procedures and mitigation measures in cooperative agreements and applicator contracts at the time the programs are funded or contracts awarded. The agreements or contracts would identify the party responsible for ensuring compliance with these critical safeguards.

## Feasibility of Eradication and Limitations of the Analysis

This section discusses the feasibility of eradication and the possibility and consequences of the failure to eradicate. The feasibility of the boll weevil eradication program has been questioned by many groups for both scientific and socioeconomic reasons. These concerns include possible environmental effects from implementing the planned program. One main area of disagreement is in defining eradication and the philosophical ideologies that the definition can represent.

Newsom (1978) describes many different ways in which eradication is defined. Eradication generally means elimination of every individual member of a species. In addition, he states, the objective target, as well as the geographic area, must be defined to limit the scope of the project. The amount of time required for the eradication to be completed must also be considered. In some instances, eradication may be defined differently. Often a definition describing a different threshold for eradication is used. Selecting a threshold such as "no detectable levels" can make eradication more easily verifiable than a definition of complete, absolute elimination of the species from an area. In a similar article, Rabb (1978) explains the philosophy of eradication. He states that the ideas of eradication and integrated pest management are

mutually exclusive. This causes much friction between factions when determining regulatory policy and program implications. The use of organophosphate pesticides for eradication, which may possibly aid in the development of pesticide-resistant strains of secondary pests that may be very difficult to control, pits integrated pest management proponents against eradication proponents.

Many judgments against the feasibility of eradication often rest on different sets of assumptions than judgments in favor of eradication. Neither set of assumptions is incorrect. This points out the difficulty in trying to develop a scientific consensus about eradication.

A report from USDA on eradication theory and practice lists two scientific review committees that were undecided about the program's feasibility. The Entomological Society of America was divided on continuation of the program without further research on suppressive technique development. The National Academy of Sciences appointed a committee on Cotton Insect Management, which recommended against an eradication program (Klassen, 1989).

Risk is always associated with any attempt to control or eradicate a pest. Moreover, control activities cannot be guaranteed to produce the desired results. The boll weevil eradication program is no different. Program experience indicates that eradication is an achievable goal; however, it is possible that the program could fail.

Failure to eradicate the boll weevil could have several of the following consequences:

- The establishment of permanent buffer zones to prevent reinfestation.
- Previously eradicated areas would have to be protected indefinitely.
- If cotton growers in the buffer zones withdrew their support for areawide boll weevil control, the buffer zones would have to be moved into previously eradicated areas.
- Eventually, all the eradicated areas could be reinfested.
- The benefits of boll weevil eradication in Virginia, North and South Carolina, Georgia, southern Alabama, California, Arizona, and New Mexico would be lost.
- Each cotton grower would revert to an "every man for himself" approach to pest control. As history has clearly demonstrated, weevils reared on the few poorly managed farms would again infest all the farms in the nearby community.
- Insecticide use would likely increase, returning to pre-eradication levels as areas become reinfested.

- The total amount of insecticide used and the number of compounds used would almost certainly increase if the boll weevil is not eradicated.

Additional information about the consequences of program failure is available in "Cotton Boll Weevil: An Evaluation of USDA Programs," by National Academy Press, 1981. (p. 58-103).

# Chapter 3

# The Affected Environment

## Overview

This chapter describes the environment that would be affected by the implementation of the National Boll Weevil Cooperative Control Program. The affected environment includes cotton fields as well as adjacent nonagricultural areas that may be affected by boll weevil control activities in the following States: Alabama, Arizona, Arkansas, California, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

The affected environment may be described in terms of resource elements, which include geology, climate, soils, vegetation, terrestrial and aquatic species, and water quality. This chapter also describes characteristics of the human environment that may be affected by the implementation of the boll weevil control program and includes a general description of the population of Cotton Belt States, special groups that may be particularly sensitive to control activities, characteristics of the agricultural portions of Cotton Belt State economies, cultural and visual resources, noise, and ambient air.

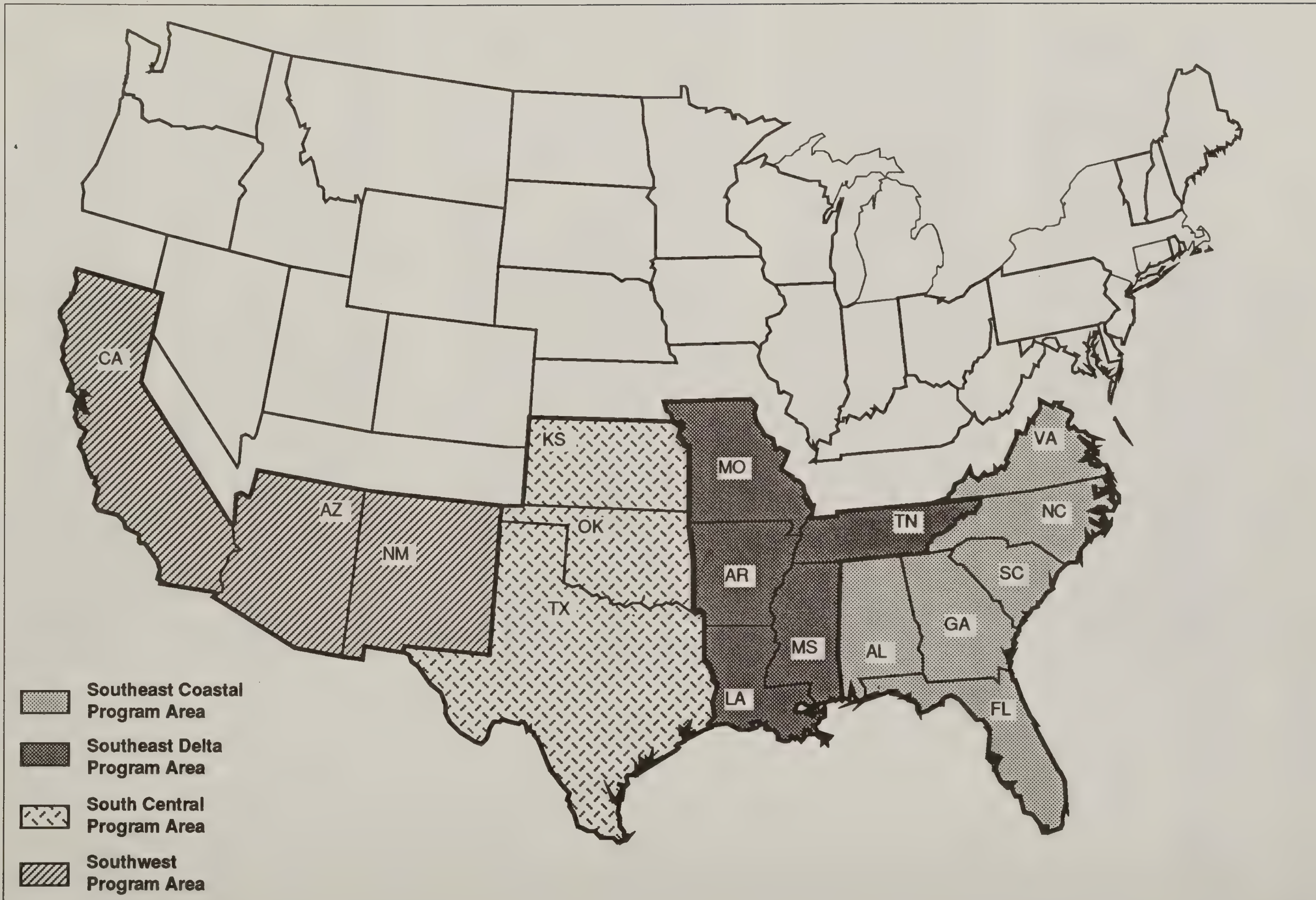
Within each resource section, the discussion is organized by geographic area: the Southeast, which includes the cotton-producing States east of the western borders of Arkansas, Louisiana, and Missouri; the South Central, which includes Texas, Oklahoma, and Kansas; and the Southwest, which includes California, Arizona, and New Mexico. Also, in the discussion, the Southeast area is subdivided into the Coastal subarea (Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama) and the Delta subarea (Tennessee, Louisiana, Mississippi, Arkansas, and Missouri). Figure 3-1 shows the program analysis areas. These areas represent distinct cotton-growing regions that differ in agronomic practices, cotton variety, and surrounding nonagricultural environment.

While the program areas depicted in figure 3-1 do not precisely correspond to the APHIS Plant Protection and Quarantine (PPQ) regional organization, dividing the Cotton Belt this way facilitates the discussion of regional differences. The program implementation increments, discussed in chapter 2, would also span PPQ regional boundaries for biological reasons. The Southeast region includes all cotton-producing States east of the Mississippi River; the South Central region includes Arkansas, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas; and the Western region includes Arizona and California.

## Cotton Belt Land Use

Land uses in the Cotton Belt States are diverse and include livestock grazing, outdoor recreation, forested lands, urban developments, and cropland. Land used for crops represents a relatively small percentage (18.5 percent) of the total land area in the Cotton Belt States; in approximately two-thirds of these States, cropland constitutes fewer acres than

Figure 3-1. Program Areas



pastures, grassland, rangeland, Federal and State recreation areas, military areas, and rural transportation (roads, airports, and so forth) (USDA, 1990).

In 1987 land devoted to cotton production represented 1.2 percent of the total land area of Cotton Belt States and 9 percent of the total crop acreage (USDA, 1990). Though this percentage may seem small, in most States cotton production is widely distributed, so adverse economic effects from boll weevil damage are widespread.

Cotton is produced in a variety of environments. Requisites common to all areas are a long growing season, fertile soil, warm temperatures, and adequate soil moisture. The oldest production area is the warm, humid Southeast, where soil moisture is dependent on rainfall. The arid South Central and Southwest States, where irrigation supplies most of the soil moisture, are the most recently developed cotton-growing areas.

The length of the growing season varies with cotton variety, ranging from 120 to 210 days. Short-season cotton varieties are primarily adapted to conditions in the South Central and Southeast program areas. Long-season varieties, including pima and acala, are grown in the irrigated deserts of Arizona and New Mexico and in the San Joaquin Valley in California.

The size and distribution of cotton fields vary across the Cotton Belt. In the older cotton-growing areas of the Southeast, cotton fields are often small (less than 30 acres), noncontiguous plots located near rural houses and wooded areas. Also in the Southeast, cotton may be grown in small plots within municipal limits. Although few cotton fields in the Southeast are irrigated, some fields are near or adjacent to rivers and streams. Historically, this was because of a reliance on water for transporting the raw cotton. In addition, many fields were located on flat floodplains that were generally easier to cultivate.

In the newer cotton-growing areas of the South Central and Southwest regions, cotton is most often grown in large, contiguous plots. In these areas, the average field is 100 acres. Fields are more often bounded by roads or "turn rows" than by residential areas or wooded habitats. Turn rows are rows purposefully left unplanted to allow vehicles and farm equipment access to fields not bordered by roads. In the arid Southwest, 90 to 100 percent of the fields are irrigated. In Texas and Oklahoma, only one-third of the fields are irrigated.

## Geology

Landforms and geology affect cotton production and the prevalence of boll weevils in several ways. Cotton production is feasible only where the terrain is relatively flat because heavy equipment is used to cultivate and harvest the crop. Hilly or mountainous terrain would not support significant cotton production. Landforms also affect local and regional weather. In the West, precipitation patterns are highly influenced by the mountain ranges; storm fronts primarily move from the

west and drop their precipitation on the westward side of the mountains. Because of this weather pattern and the dryness to the east of mountain chains, cotton in these areas can be grown only with intensive irrigation. Landforms such as the Cap Rock in northern Texas can also serve as barriers to boll weevil dispersal, although recent evidence indicates that boll weevils can cross this barrier. The soil parent material largely determines its suitability for cotton production and the degree to which soil amendments (such as fertilizers) must be used to produce a healthy crop.

## Southeast Program Area

The Southeast program area, which is subdivided into the coastal and delta subareas, includes the physiographic areas of the Atlantic and Gulf Coastal Plains that are separated by the Alabama-Georgia border; the Interior Highlands; the Piedmont, Blue Ridge, and Ridge and Valley provinces; and the Appalachian Plateau. Figure 3-2 illustrates the location of these areas.

### Coastal Subarea

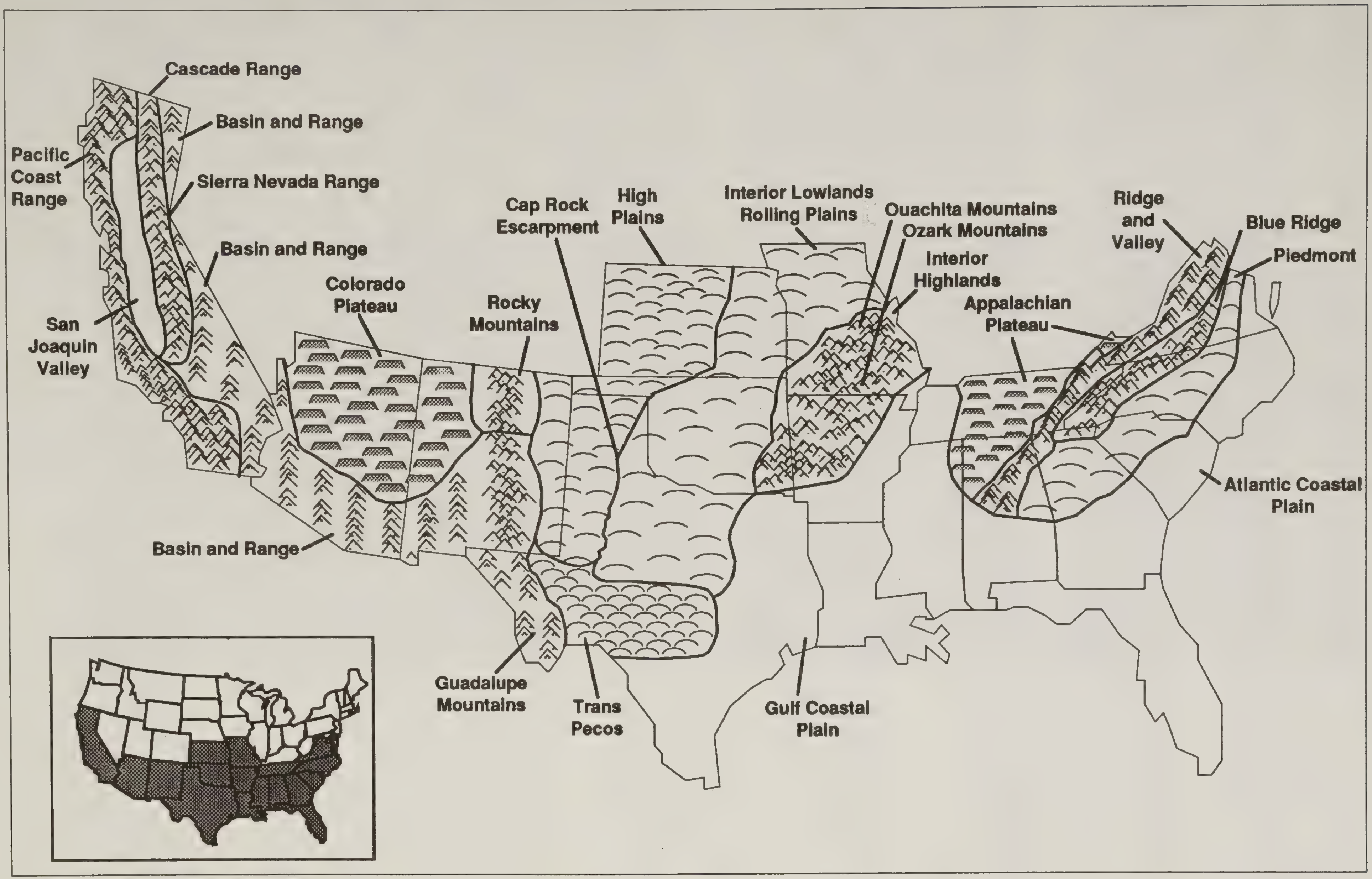
The Atlantic Coastal Plain (Florida, southern Alabama, and Georgia) and the Piedmont (eastern South Carolina, North Carolina, and Virginia) were formed from long-term sedimentation into a slightly sloped basin. The Piedmont has low, rolling relief, and it developed on metamorphic and igneous rocks. The flatter Coastal Plain is made of a thick wedge of sedimentary rocks that include sandstone, siltstone, shale, and limestone (Clark and Stearn, 1968; Press and Siever, 1974). Streams and rivers carry sediment to the Gulf and Atlantic coasts where it is deposited offshore (Clark and Stearn, 1968).

The Blue Ridge Mountains form the eastern edge of the Appalachian Mountains. They contain uplifted pre-Cambrian igneous and metamorphic rocks. The Blue Ridge and Ridge and Valley provinces represent a transitional sequence from the rolling nature of the Piedmont (Clark and Stearn, 1968). Cotton fields in northern Alabama are located at the southern end of the Ridge and Valley province, and those in northern Georgia are located at the extreme southern portion of the Blue Ridge province (fig. 3-2). The Appalachians to the west and north of the Blue Ridge have eroded to a series of ridges and valleys, and the topography is hilly to rolling (Clark and Stearn, 1968). A latticelike array of rivers is found parallel or perpendicular to the ridges. Differentially eroded igneous, metamorphic, and sedimentary rocks exposed in these units contribute to the varied nature of the topography (Press and Siever, 1974). Further erosion of material on the western flanks of the Appalachians formed the Appalachian Plateau province.

### Delta Subarea

The Gulf Coastal Plain is the dominant physiographic region in the Delta program subarea (fig. 3-2). The geology underlying the Gulf Coastal Plain is similar to that of the Atlantic Coastal Plain. The Mississippi Embayment extends 500 miles from southern Illinois to the

Figure 3-2. Landforms of the Program Areas




Source: Raisz 1954; Kingston 1987; Hunt 1967

Gulf of Mexico between the Ouachita and Ozark Mountains and the Appalachian Mountains (Clark and Stearn, 1968).

The eastern portion of the Interior Highlands has limited cotton production. The Highlands, which include the Ouachita Mountains, are the westward continuation of the Appalachian Mountains formed under compression. A small amount of cotton production in this program subarea occurs within the western portion of the Appalachian Plateau. The topography of this program subarea ranges from flat in Louisiana and Mississippi to rolling in Arkansas, Tennessee, and Missouri. Rivers and streams meander throughout the region, sometimes creating oxbow lakes.

## South Central Program Area

Many different physiographic units lie within the South Central program area. Portions of the High Plains and interior lowlands (Rolling Plains) are located in western Texas and Oklahoma (fig. 3-2). Southwestern Texas is dominated by the Guadalupe Mountains, an extension of the Rocky Mountains. The Gulf Coastal Plain includes a large part of southeastern Texas. The Trans Pecos unit can be characterized by its hilly topography, which is dramatically different from the Gulf Coastal Plain to the east, the mountainous area to the west, and the High Plains and Rolling Plains to the north. Although these units differ, cotton thrives in each environment. Plateaus in the mountainous areas of Oklahoma and northwestern Texas are hospitable for cotton, as are the flat plains of southern and eastern Texas.

The largest contiguous tract of cotton in the world, spanning 3.2 million acres, is located above the Cap Rock Escarpment on the High Plains in northwestern Texas. This escarpment is an ancient geologic feature caused by surface erosion of the underlying limestone. In many places it forms a striking natural boundary between the High Plains above and the eastern Rolling Plains below. The High Plains' harsh winters and lack of overwintering habitat present an environmental barrier at the eastern edge of the escarpment to the western movement of the boll weevil into the Texas and New Mexico High Plains. Although it is generally thought that the boll weevil cannot survive the High Plains winters, occasional infestations along the Cap Rock in the High Plains have increased to destructive levels and have required treatment. Small numbers of weevils are capable of overwintering in the High Plains if suitable habitat is available (according to a personal communication with Don Rummel, 1989).

Thick carbonate formations, sandstones, and shales are the most common rock types in the South Central program area. The Rocky Mountains in the western portion of Texas were formed by compressive forces at the end of the Cretaceous period, believed to have occurred about 60 million years ago (Clark and Stearn, 1968). Rivers and streams in this area are slightly meandering; some are seasonal and may be observed only during winter or spring, when precipitation most often occurs.

### Southwest Program Area

The Rocky Mountains, Basin, and Range; Colorado Plateau; and Pacific Coast Range make up the main physiographic units in the Southwest program area (fig. 3-2). In the Basin and Range province, the southern portions of New Mexico, Arizona, and California support cotton production. New Mexico has cotton production in the Rocky Mountains and High Plains areas. The Imperial and San Joaquin Valleys of California are also principal cotton-producing areas (fig. 3-2).

The geology of the Southwest program area is extremely complex. Periods of basin sedimentation, volcanism, and igneous intrusion, as well as crustal plate extensions and compressions, have disrupted the previous geology. Sandstone, limestone, dolomite, and shale are common in this area, as in the other program areas; however, rocks formed under extreme pressure and temperature, which are found in the Southwest, are rare or nonexistent in the other program areas (Clark and Stearn, 1968). The San Joaquin Valley was formed from the compression of rocks on the west and is bordered on the east by the Sierra Nevada Mountains.

The highest reaches of the mountainous areas receive a substantial amount of snow. In spring, snowmelt draining from the mountains spawns a number of intermittent (seasonal) streams. The relief in this program area ranges from nearly flat in the San Joaquin Valley to mountainous in parts of Arizona and New Mexico.

## Climate

The general climate of each program area depends on prevailing winds, surrounding terrain, elevation, and proximity to bodies of water. Because the weather in any program area is broadly predictable based on certain factors (temperature, rainfall, and freeze and thaw dates), cotton production can be assumed to be fairly predictable over the duration of a boll weevil control program.

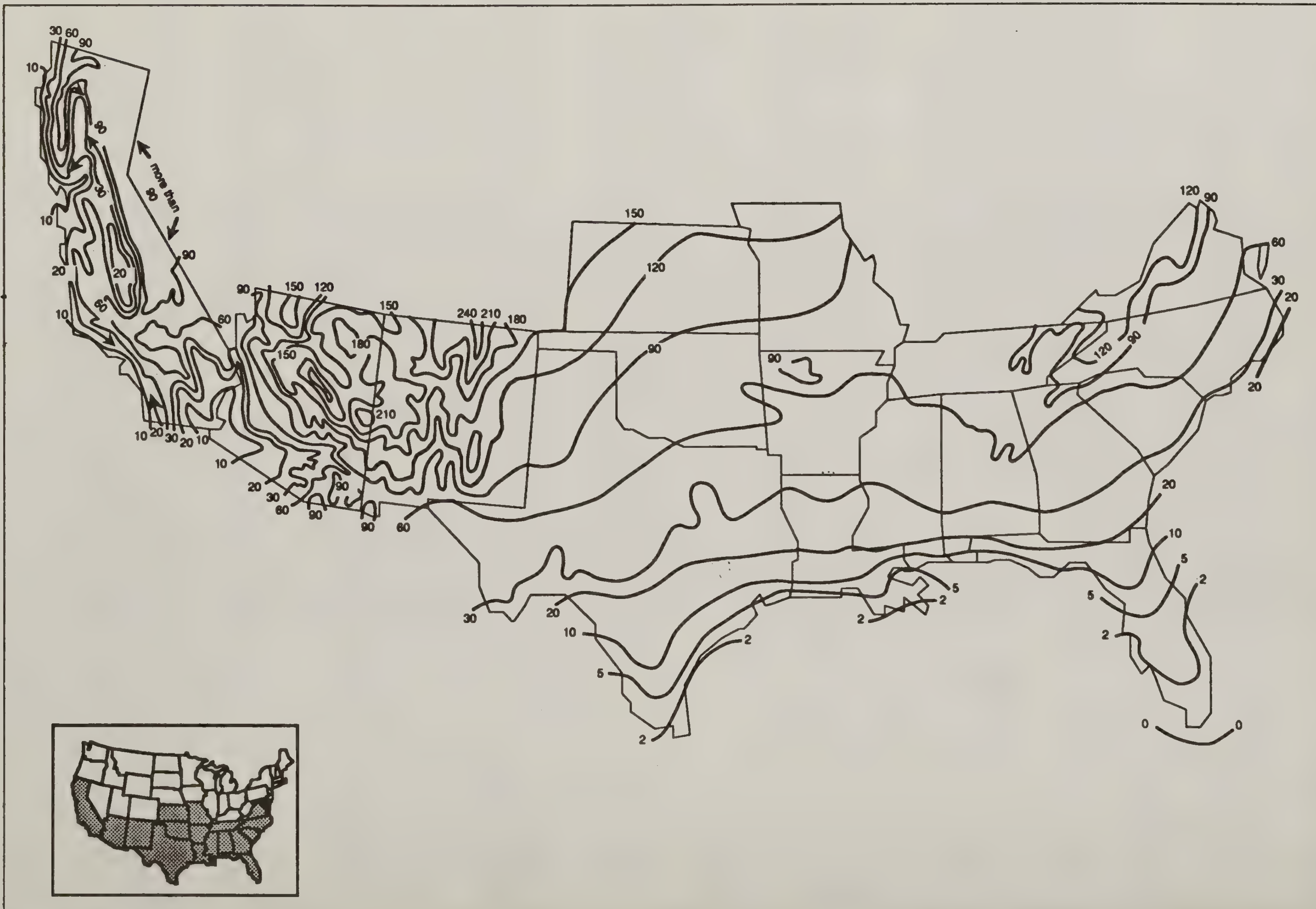
### Southeast Program Area

The climate of the Southeast program area is humid and temperate. Minimal climatic differences exist between the Delta and Coastal subareas. Climatic contours tend to correspond to coastal areas and the Appalachian Mountains (figs. 3-3 through 3-6). Annual precipitation ranges from 44 inches in South Carolina and Georgia to 64 inches in Florida. On the average, less than 6 inches is attributable to snowfall. In this program area, fewer than 90 days per year have minimum temperatures below freezing (32°F) (fig. 3-3). Most of the area has fewer than 60 freezing days per year. The last freeze date in the spring is around April 10, and an average of more than 210 freeze-free days can be expected before the first autumn freeze around October 30 (figs. 3-4, 3-5, and 3-6). Average June temperatures are above 75°F (DOC, 1983).

### South Central Program Area

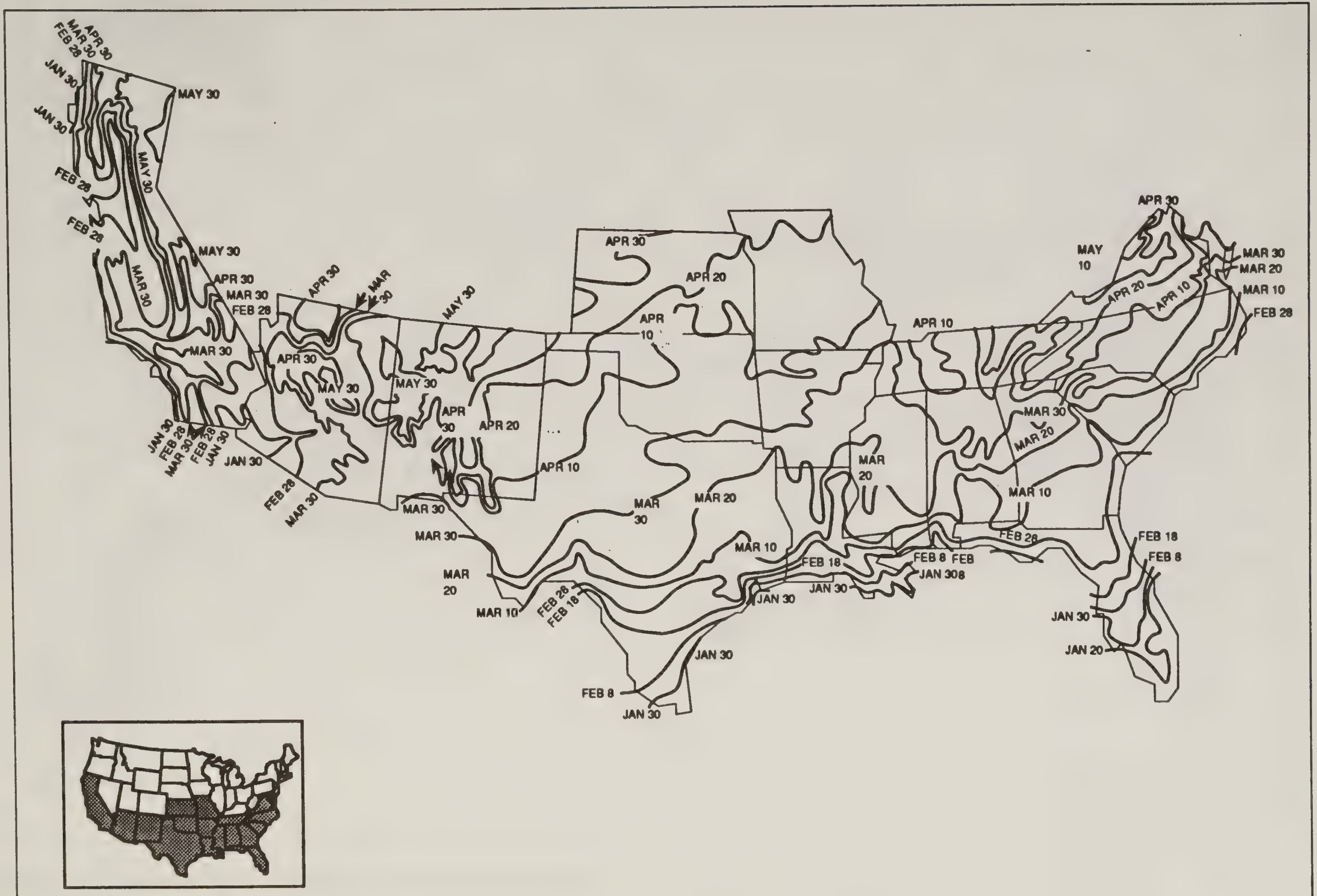
The South Central program area is hot in the summer and relatively dry year-round. Humidity is somewhat higher near the coast than in the rest of the program area. Annual precipitation ranges from 8 inches in the vicinity of El Paso, Texas, to 48 inches near Galveston, Texas, on the average. Less than 12 inches is attributable to snowfall in the

Figure 3-3. Mean Annual Number of Days Minimum Temperature is 32°F and Below




Source: DOC 1983.

## Figure 3-4. Mean Date of Last 32°F Temperature in Spring

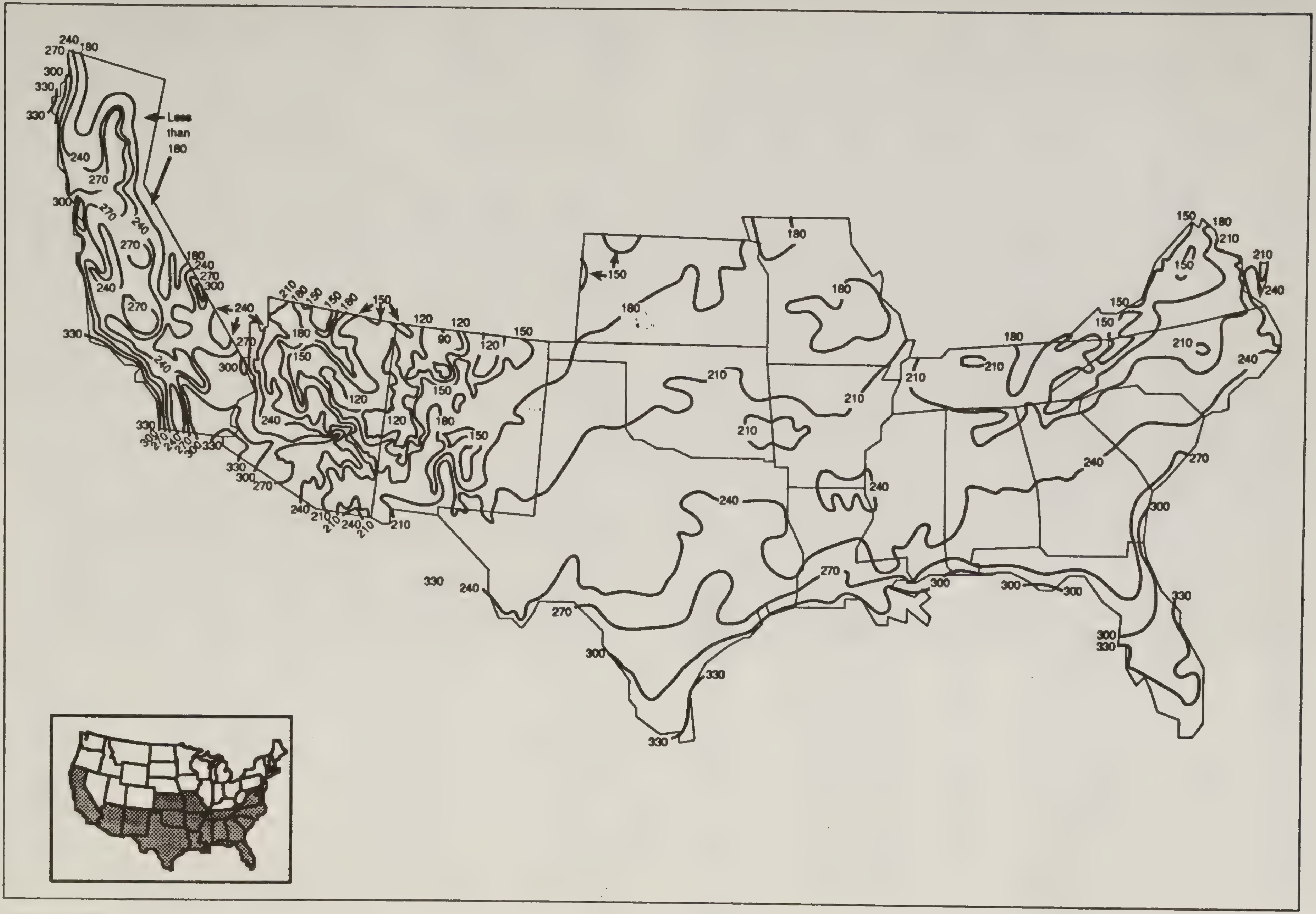



Source: DOC 1983.

**Figure 3-5. Mean Date of First 32°F Temperature in Autumn**


**Source:** DOC 1983.

Figure 3-6. Mean Length of Freeze-free Period (Days) Betweeen First and Last 32°F in Spring




Source: DOC 1983.

program area. The program area has fewer than 90 days per year when minimum temperatures are below freezing (fig. 3-3). As in the Southeast program area, the last date for freezing temperatures in the spring is around April 10, and an average of more than 210 freeze-free days can be expected before the first autumn freeze around October 30 (figs. 3-4, 3-5, and 3-6). Average June temperatures are above 75°F, with most of Texas having average temperatures above 80°F (DOC, 1983).

### Southwest Program Area

The summer climate in the Southwest program area is hot and dry in the southern portions of California, Arizona, and New Mexico. Annual normal temperature and precipitation patterns are similar to those of the South Central program area. A more temperate environment exists in the San Joaquin Valley of California. The total annual precipitation in the program area is generally less than 24 inches per year, with most of the area receiving less than 12 inches per year; on the average, less than 12 inches is attributable to snowfall. Most of the program area has fewer than 90 days per year when minimum temperatures are below freezing (fig. 3-3); areas in eastern New Mexico tend to have more cool days than the rest of the cotton-growing areas in the region. The last date for freezing temperatures in the spring is around April 20, and an average of more than 180 freeze-free days can be expected before the first autumn freeze around October 30 (figs. 3-4, 3-5, and 3-6). This program area has fewer frost-free days than the South Central region, primarily because of the higher elevations of the Southwest. Average June temperatures are above 75°F (DOC, 1983).

## Soils

Soils are composed of both inorganic and organic matter. Rocks undergo weathering to form the inorganic portion of the soil; therefore, the type of soil is partially dependent on the composition of the underlying rock. Organic matter can be derived from plant material or organisms that decay and become incorporated into the soil. The slope of the area where weathering takes place, the water content of the rocks, the climate, and past uses of the land can also affect soil development (Strahler and Strahler, 1978). For example, soils in flat, humid areas will not drain as well as those in rolling terrain.

Growers must often use fertilizers to supplement the natural elements in the soil that are lost as a result of cotton production. Nitrogen, an important nutrient, must often be added to soils where cotton is grown. Crop rotation with legumes is a common technique growers use to enhance soil fertility.

Although soils in the same locale may vary significantly because of geology, climate, topography, and land-use history, cotton plants can thrive in almost any type of soil, given adequate moisture levels and sufficient soil nutrients. Infestation of cotton by the boll weevil is independent of soil type. Cotton is grown in a variety of soil orders: Ultisols, Entisols, Inceptisols, Vertisols, Mollisols, Alfisols, and Aridosols. Each order is briefly described below.

Ultisols are well-developed acid soils with strong clay accumulation in the subsoil and intense leaching of bases. These soils are moderately productive (Brady, 1974).

Entisols are undeveloped soils that are low in organic matter or clay accumulation. These soils are typically unproductive.

Inceptisols are poorly developed, often shallow, acid soils with thin topsoil and little clay accumulation in the subsoil. Inceptisols also are typically unproductive. Both entisols and inceptisols are, however, quite productive in river valleys because of the high levels of nutrients and soil moisture from flood deposition.

Vertisols are mixed clays that crack when dry and are highly productive (Brady, 1974).

Mollisols, thick and rich in organic matter, have a high base saturation and do not become hard when dry. When they are first cleared for cultivation, their high native organic matter releases sufficient nitrogen and other nutrients to produce bumper crops—even without fertilization. Mollisols are among the most productive cultivated soils in the world (Brady, 1974).

Alfisols are well-developed soils with clay accumulation in the subsoil and slight leaching of bases. These soils are highly productive.

Aridosols are mineral soils that are dry most of the year. They are generally low in organic matter and may have accumulations of soluble salts and calcium carbonate. Without irrigation, Aridosols are not suitable for growing cultivated crops, but where irrigation is available, these mineral soils can be very productive (Brady, 1974).

## Southeast Program Area

### Coastal Subarea

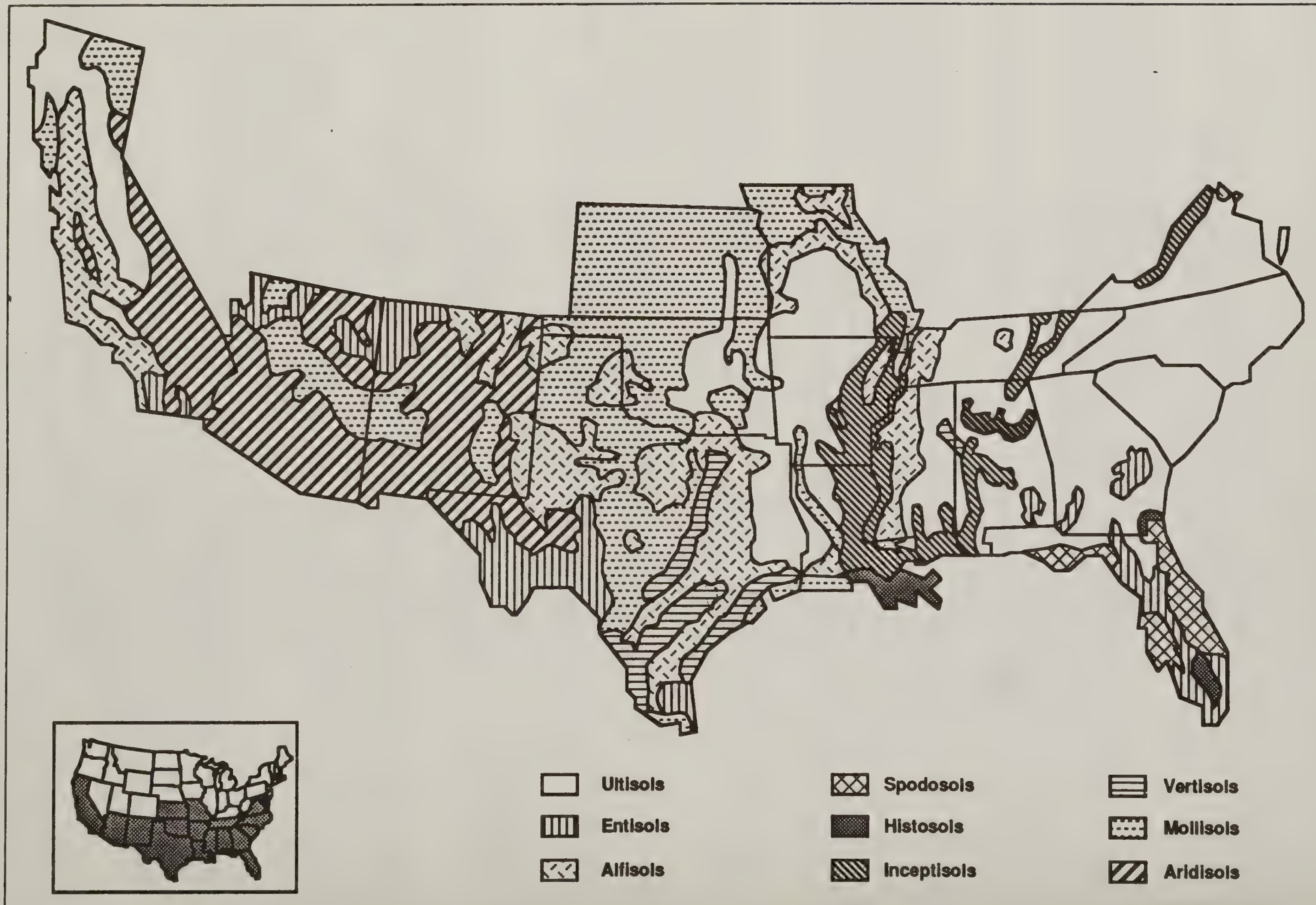
Four soil orders are predominant in the cotton-growing areas of the Coastal subarea (fig. 3-7): Ultisols, Entisols, Inceptisols, and Vertisols (Brady, 1974). Of the four, Ultisols are predominant in this program subarea. Two other soil orders, Spodosols and Histosols are also found in this subarea, but cotton is not grown in these soils.

Seasonally saturated Ultisols prevail in the eastern coastal area and are associated with organic soils in swamps (Brady, 1974). Entisols occur largely as acidic, permeable sands in southern Georgia and Alabama. Inceptisols occur primarily in thin bands in Alabama and are the dominant soil type in the Appalachian Mountains. Vertisols are found in Alabama's clay lowlands (Brady, 1974).

### Delta Subarea

Although Ultisols are the dominant soil order in States in the Delta subarea, most of the area's cotton is grown in Inceptisols along the

Figure 3-7. Patterns of Soil Orders and Suborders of the Program Area




Source: Brady 1974.

Mississippi River (fig. 3-7). The Delta subarea does not have Entisols, but near rivers it does have Mollisols and Alfisols (Brady, 1974).

### South Central Program Area

The South Central program area does not have a dominant soil type for producing cotton (fig. 3-7). Soil orders of this region include Alfisols, Aridosols, Entisols, Mollisols, Ultisols, and Vertisols (Brady, 1974). Alfisols are predominant in the clay prairies of Texas (fig. 3-7).

### Southwest Program Area

The dominant soil order of the Southwest program area is the Aridosols (fig. 3-7). In the Western United States, irrigated valleys containing Aridosols are among the most productive in the world. Other common soil orders in the Southwest program area include the Alfisols, Entisols, and Mollisols (Brady, 1974).

## Vegetation

The diversity of native vegetation found near agricultural systems in the Cotton Belt of the United States reflects the different climatic conditions under which cotton is grown. Vegetation community types range from temperate deciduous forests and woodlands in the Southeast coastal subregion to warm semidesert scrub in the arid Southwest.

In areas where cotton is grown in large, contiguous tracts, such as the High Plains, adjacent native vegetation is reduced to small, immature stands of grassland vegetation around field borders and on highway shoulders. Conversely, native vegetation adjacent to small, isolated cotton fields in the Southeast often consists of mature stands of deciduous or coniferous woodland. In this area and other areas of the Cotton Belt, predominant adjacent vegetation includes other agricultural crops, such as soybeans, corn, and peanuts.

Examples of native vegetation found in each program area are described in the following sections. A more comprehensive list of representative vegetation species appears in appendix F. (Information for describing the vegetation found in the program areas was compiled from several sources, including Audubon Society Nature Guides (Sutton and Sutton, 1985; Brown, 1985; MacMahon, 1985; Whitney, 1985), USDA publications (USDA, 1981; USDA, 1987; USDA, 1988; Garrison et al., 1977), forestry symposium proceedings (Sheffield et al., 1983), and textbooks (Harlow and Harrar, 1969; Scott, 1984).)

A biological assessment has been prepared to determine any effects to listed and proposed endangered and threatened plant species that may be present in program areas. A summary of the biological assessment can be found in appendix H.

### Southeast Program Area

The Southeast program area contains many different types of vegetation, including the oak-hickory forest of the Ozark Highlands, the mixed deciduous forests of the southern Appalachian foothills, the bayous of Louisiana, and the pinelands of Georgia.

The dominant vegetation of the Coastal Plain consists of mixed pine and hardwood forests, commonly called loblolly-shortleaf-hardwood forests. These forests stretch from southern Virginia through the

Carolinas, central Georgia, Alabama, Mississippi, western Louisiana, and into eastern Texas (fig. 3-8). The predominant trees are loblolly (*Pinus taeda*) and shortleaf pine (*Pinus echinata*). Various species of oak (*Quercus* spp.) and hickory (*Carya* spp.) are commonly associated with the pines and make up the midstory and understory, along with sweetgum (*Liquidambar styraciflua*), persimmon (*Diospyros virginiana*), red maple (*Acer rubrum*), elm (*Ulmus* spp.), black gum (*Nyssa sylvatica*), and yellow poplar (*Liriodendron tulipifera*). Shrubs and vines common to these forests include viburnums (*Viburnum* spp.), American beautyberry (*Callicarpa americana*), and hawthorns (*Crataegus* spp.). The principal grasses are bluestems (*Andropogon* spp.), panicums (*Panicum* spp.), and spikegrasses (*Uniola* spp.); common forbs include tickclovers (*Desmodium* spp.), ragweed (*Ambrosia* spp.), and goldenrod (*Solidago* spp.).

Along the Atlantic and Gulf coasts and in parts of South Carolina, Georgia, Alabama, Mississippi, northern Florida, and west central Louisiana, forests are predominantly longleaf pine (*Pinus palustris*) and slash pine (*Pinus elliottii*) (fig. 3-8). Associated trees include other southern pines (*Pinus* spp.), oak species (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), and southern magnolia (*Magnolia grandiflora*). Shrubs and vines found in longleaf-slash pine forests include saw palmetto (*Serenoa repens*), gallberry (*Ilex* spp.), and greenbriar (*Smilax* spp.). Bluestem grasses (*Andropogon* spp.) are the dominant herbaceous vegetation in these forests west of the Apalachicola River in the Florida panhandle. Wiregrasses (*Aristida* spp.) are dominant to the east. Common forbs and ferns include tickclover (*Desmodium* spp.), lespedezas (*Lespedeza* spp.), and cinnamon fern (*Osmunda cinnamonea*).

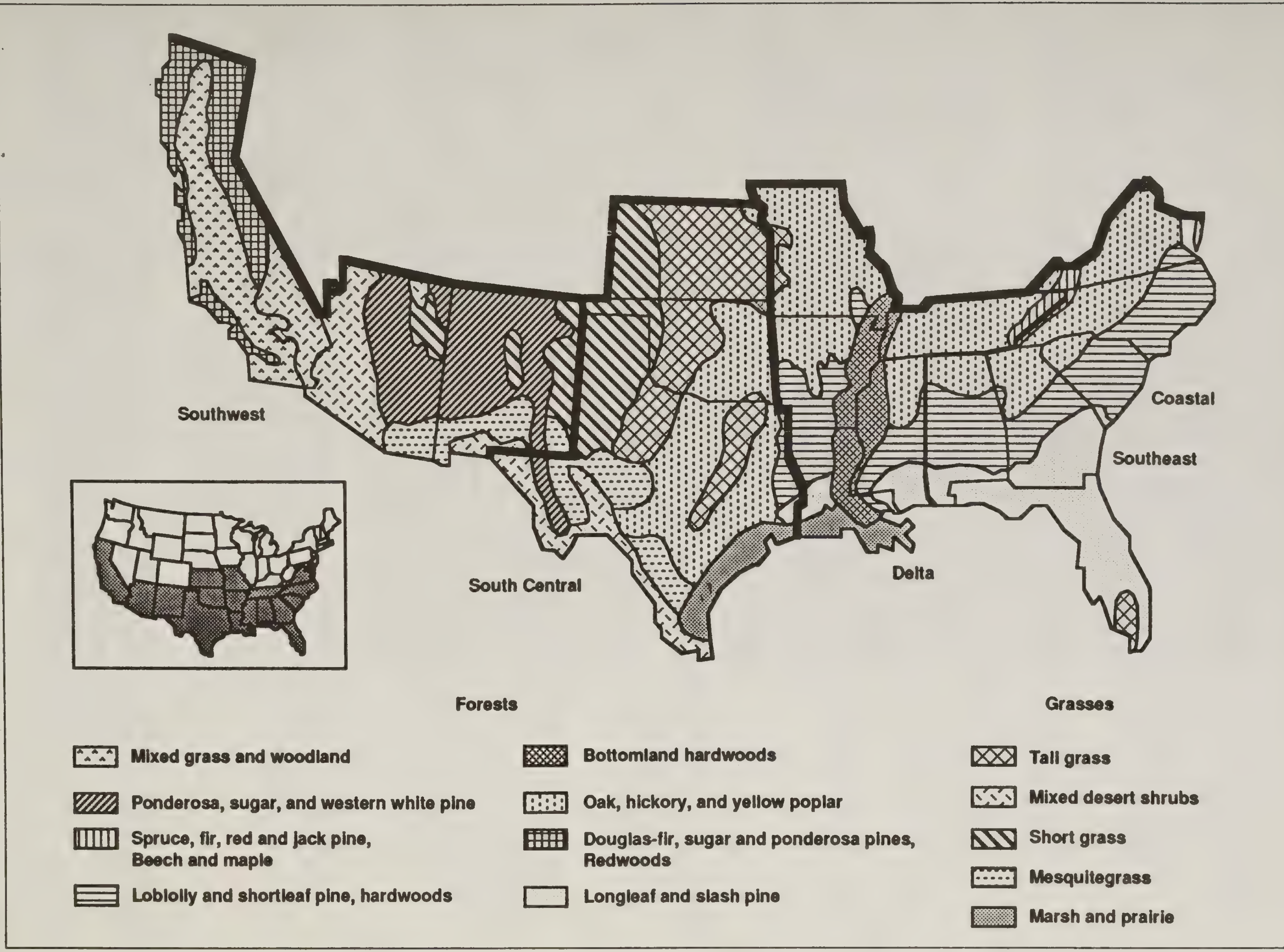
The Mississippi Valley and other low-lying areas near southeastern rivers have bottomland forests that consist mostly of black tupelo (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), bald cypress (*Taxodium distichum*), and oak (*Quercus* spp.). Other common trees include red maple (*Acer rubrum*), cottonwood (*Populus deltoides*), American elm (*Ulmus americana*), and river birch (*Betula nigra*). Shrubs and vines include buttonbush (*Cephalanthus occidentalis*), strawberry bush (*Euonymus americanus*), greenbriar (*Smilax* spp.), and trumpet creeper (*Campsis radicans*). Grasses include switchgrass (*Panicum virgatum*), eastern gramagrass (*Bouteloua* spp.), little bluestem (*Andropogon scoparius*), and indiangrass (*Sorghastrum nutans*).

In the Coastal subarea, cotton is grown next to other crops, such as peanuts, corn, soybeans, and tobacco, as well as near fallow fields and next to loblolly-shortleaf pine and longleaf-slash pine forests. In the Delta subarea, cotton also is grown next to crops such as soybeans and near bottomland hardwood trees and associated vegetation.

## South Central Program Area

While much of the land in this area has been converted to farms and ranches, grasses are the dominant natural vegetation of the South Central area (fig. 3-8). Short-, mixed-, and tall-grass prairies stretch down from the north and characterize noncrop vegetation in the northern half of this program area. The short grasses, blue grama (*Bouteloua*

Figure 3-8. Major Vegetation Zones of the Cotton-producing States



gracilis) and buffalo grass (*Buchloe dactyloides*), are dominant in the western parts, while little bluestem (*Andropogon scoparius*) is prevalent to the east. Other common grasses include sideoats grama (*Bouteloua curtipendula*), Junegrass (*Koeleria cristata*), indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardi*), switchgrass (*Panicum virgatum*), and needlegrass (*Stipa spartea*). Although woody vegetation is rare, it occurs more to the north and northeast. Open stands of post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*), with understories of sunflower (*Helianthus* spp.), lespedezas (*Lespedeza* spp.), and grass, occur in central parts. Juniper trees (*Juniperus* spp.) grow on escarpments; oaks (*Quercus* spp.), elms (*Ulmus* spp.), cottonwood (*Populus deltoides*), hackberry (*Celtis occidentalis*), and pecan trees (*Carya illinoensis*) grow near rivers.

Vegetation in southwestern Texas ranges from desert-shrub in the western parts to grasslands in the Rio Grande Plain. The sparse vegetation and thorny bushes of extreme southwest Texas grade to short- and mid-grasses and then to mixed oak savanna from west to east across the Edwards Plateau. The Rio Grande Plain in southern Texas is mostly open grasslands with scattered woody plants. Common grasses here are little bluestem (*Andropogon scoparius*), plains bristlegrass (*Setaria macrostachya*), plains lovegrass (*Eragrostis intermedia*), switchgrass (*Panicum virgatum*), and sideoats grama (*Bouteloua curtipendula*). Shrubs and forbs found here include catclaw (*Acacia greggii*), honey mesquite (*Prosopis grandulosa*), and daleas (*Dalea* spp.).

In the northeast parts of this program area, the Ozark Highlands, Arkansas Valley, and Ouachita Mountains with their oak-hickory-pine vegetation extend into eastern Oklahoma (fig. 3-8). South of these forests are the pine-hardwood forests of the Western Coastal Plain. Oak (*Quercus* spp.), hickory (*Carya* spp.), and pine (*Pinus* spp.) exist in both forests, with oak and hickory predominant in the north, and loblolly (*Pinus teada*) and shortleaf pines (*Pinus echinata*) dominant in the south. Grasses and different forbs and shrubs make up the understory. Appearing along the Gulf Coastal Plain in southwestern Texas is prairie vegetation of little bluestem (*Andropogon scoparius*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and big bluestem (*Andropogon gerardi*). Live oak (*Quercus virginiana*) appears in dispersed groves.

In the southern High Plains area, cotton is grown as a monoculture and is rarely found near other crops. In other areas, such as the Blacklands in central Texas, cotton grows near grain sorghum and corn in the summer; in the winter, it is sometimes double-cropped with small grains, such as wheat. On the Gulf Coast, cotton is grown near soybeans, grain sorghum, and range grasses.

## Southwest Program Area

The dryness of the Southwest program area is reflected in the vegetation found there. Desert grassland is found in southern New Mexico and southeastern Arizona. Common features include grasses, such as the grama grasses (*Bouteloua* spp.); succulents, such as prickly pear (*Opuntia polycantha*) and giant saguaro cactus (*Cereus giganteus*); semi-

succulents, such as yucca (*Yucca* spp.); and shrubs, such as the creosote bush (*Larrea tridentata*). Other vegetation found in the desert grasslands includes tobosa grass (*Hilaria mutica*), mesquite (*Prosopis* spp.), bur sage (*Ambrosia deltoidea*), and ocotillo (*Fouquieria splendens*). Common plants found in the Sonoran and Mojave deserts, located in southeastern California and southwestern Arizona, include bur sage (*Ambrosia deltoidea*), creosote bush (*Larrea tridentata*), yucca (*Yucca* spp.), cactus (*Cactaceae*), joshua tree (*Yucca brevifolia*), galleta (*Hillaria* spp.), and mormon tea (*Ephedra* spp.).

Fir-pine forests are found in the Sierra Nevada Mountains in eastern California, while to the west, much of the valley grasslands have been converted to agriculture. In addition to crops, the San Joaquin Valley of California supports many different introduced annuals, such as wild oats (*Avena fatua*), soft chess (*Bromus mollis*), foxtail fescue (*Festuca megalura*), and California brome (*Bromus carinatus*). Oak appears on terraces, along with cottonwood and willow, near rivers and streams.

In the Southwest program area, cotton is grown with the help of irrigation amidst the dry climate vegetation. Other crops grown there include chili peppers, lettuce, pecans, and alfalfa.

## Nontarget Species

### Terrestrial Vertebrates

Small mammals, birds, and reptiles are commonly found in agricultural habitats of the United States. Most are transient and enter the fields only to forage or prey on insects. A much greater diversity of mammals, birds, reptiles, and amphibians may be found in nonagricultural habitats adjacent to cotton fields.

The following sections describe representative wildlife that may be found in cotton fields and adjacent habitats. A more complete species list appears in appendix F. (Information for descriptions of the wildlife found in the program areas was compiled from several sources, including Audubon Society Nature Guides (Brown, 1985; MacMahon, 1985; Sutton and Sutton, 1985; Whitney, 1985), a scientific study (Roach, 1973), and other wildlife books (Wernert, 1982; Scott, 1987; Conant, 1958; Burt and Grossenheider, 1964).)

A biological assessment has been prepared to determine any effects on listed and proposed endangered and threatened wildlife species that may be present in program areas. A summary of the biological assessment can be found in appendix H.

#### Southeast Program Area

Many small mammals, including the southeastern shrew (*Sorex longirostris*), eastern mole (*Scalopus aquaticus*), eastern wood rat (*Neotoma floridana*), and cottonmouse (*Peromyscus gossypinus*), as well as the eastern cottontail rabbit (*Sylvilagus floridanus*), opossum (*Didelphis marsupialis*), and white-tailed deer (*Odocoileus virginianus*), are known to

inhabit the farming areas of the Southeast. Also found are the red and gray fox (*Vulpes fulva* and *Urocyon cinereoargenteus*, respectively), mink (*Mustela vison*), the striped skunk (*Mephitus mephitus*), and the raccoon (*Procyon lotor*); the river otter (*Lutra canadensis*) is found near water. A number of insectivorous bat species also are present in the area.

Numerous insectivorous bird species known to occur near or within the area's cotton fields include the northern mockingbird (*Mimus polyglottos*), yellow-breasted chat (*Icteria virens*), orchard oriole (*Icterus spurius*), eastern kingbird (*Tyrannus tyrannus*), killdeer (*Charadrius vociferus*), purple martin (*Progne subis*), bobwhite quail (*Colinus virginianus*), field sparrow (*Spizella pusilla*), northern cardinal (*Cardinalis cardinalis*), eastern meadowlark (*Sturnella magna*), and brown thrasher (*Toxostoma rufum*) (Roach, 1973). Numerous other bird species inhabit the area or migrate to it, feeding on insects, fish, and small mammals in the forests and wetlands near cotton fields.

The Southeast program area has abundant and diverse species of amphibians and reptiles, including toads, salamanders, turtles, lizards, alligators, and snakes. Some common species include the rough green snake (*Opheodrys aestivus*), Eastern hognose snake (*Heterodon platyrhinos*), six-lined racerunner (*Cnemidophorus sexlineatus*), timber rattlesnake (*Crotalus horridus*), Eastern box turtle (*Terrapene carolina carolina*), bullfrog (*Rana catesbeiana*), and Northern cricket frog (*Acris crepitans crepitans*). Their various diets include insects, fish, birds' eggs, and even small mammals. Six-lined racerunners are occasionally found in cotton fields with sandy soil, while Fowler's toads (*Bufo woodhousei fowleri*) may appear in poorly cultivated fields (Roach, 1973).

### South Central Program Area

Large mammals found in this area include the collared peccary (*Tayassu tajaca*) in southern Texas, pronghorn (*Antilocapra americana*) in the western portion of the area, and white-tailed and mule deer (*Odocoileus* spp.) throughout the area. Coyote (*Canis latrans*), blacktail jackrabbit (*Lepus californicus*), and Eastern and desert cottontail (*Sylvilagus* spp.) are present, as are burrowing rodents, such as the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), blacktail prairie dog (*Cynomys ludovicianus*), plains pocket gopher (*Geomys bursarius*), and other small mammal species. Eastern fox squirrel (*Sciurus niger*), gray fox (*Urocyon cinereoargenteus*), armadillo (*Dasypus novemcinctus*), ringtail (*Bassariscus astutus*), and raccoon (*Procyon lotor*) also occur in the South Central region.

On the gulf coast of Texas, shorebirds such as the killdeer (*Charadrius vociferus*), long-billed curlew (*Numenius americanus*), and least sandpiper (*Calidris minutilla*) can be found. Birds found in marsh and riverine habitats include the red-winged blackbird (*Agelaius phoeniceus*), pied-billed grebe (*Podilymbus podiceps*), belted kingfisher (*Megaceryle alcyon*), ruddy duck (*Oxyura jamaicensis*), and marsh hawk (*Circus cyaneus*). Some birds found on the plateaus and plains of this program area include the wild turkey (*Meleagris gallopavo*), golden-cheeked warbler

(*Dendroica chrysoparia*), greater prairie-chicken (*Tympanuchus cupido*), mourning dove (*Zenaida macroura*), Northern bobwhite (*Colinus virginianus*), and scaled quail (*Callipepla squamata*).

Common amphibians found in this area include the bullfrog (*Rana catesbeiana*), Rio Grande leopard frog (*Rana pipiens berlandieri*), Rocky Mountain toad (*Bufo woodhousei woodhousei*), Texas toad (*Bufo compactilis*), barred tiger salamander (*Ambystoma figrinum mavortium*), and Great Plains toad (*Bufo cognatus*). Reptiles found here include the snapping turtle (*Chelydra serpentina*), Eastern collared lizard (*Crotaphytus collaris collaris*), Southern prairie lizard (*Sceloporus undulatus consobrinus*), great plains skink (*Eumeces obsoletus*), six-lined racerunner (*Cnemidophorus sexlineatus*), Eastern yellow-bellied racer (*Coluber constrictor flaviventris*), prairie ringneck snake (*Diadophis punctatis arnyi*), and the Western and prairie diamondback rattlesnakes (*Crotalus* spp).

### Southwest Program Area

In the mountains of the Southwest program area, large mammals, such as mountain lions (*Felis concolor*), bighorn sheep (*Ovis canadensis*), and black bears (*Ursus americanus*), make their homes. Badgers (*Taxidea taxus*), blacktail jackrabbits (*Lepus californicus*), white-footed mice (*Peromyscus* spp.), desert cottontails (*Sylvilagus auduboni*), kangaroo rats (*Dipodomys* spp.), harvest mice (*Rheithodontomys* spp.), wood rats (*Neotoma* spp.), grasshopper mice (*Onychomys* spp.), and pocket mice (*Perognathus* spp.) are some of the smaller mammals found here, while pronghorn (*Antilocapra americana*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*Odocoileus hemionus*) are the principal browsers. In addition, there are coyote (*Canis latrans*), bobcat (*Lynx rufus*), and in the desert areas, collared peccary (*Tayassu tajacu*). Many of the smaller mammals can be found in or around cotton fields in this area. A variety of bats, including the Brazilian free-tailed bat (*Tadarida brasiliensis*) and California myotis (*Myotis californicus*), also are present.

Birds such as the Gila woodpecker (*Melanerpes carolinus*), cactus wren (*Campylorhynchus brunneicapillus*), and verdin (*Auriparus flaviceps*) roost in cacti of the southwestern deserts, while the lark sparrow (*Chondestes grammacus*), Brewer's blackbird (*Euphagus cyanocephalus*), and loggerhead shrike (*Lanius ludovicianus*) can be found in the grassy California Valley. Greater roadrunners (*Geococcyx californianus*); quail (*Callipepla* spp.); and predatory birds, such as the golden eagle (*Aquila chrysaetos*), American kestrel (*Falco sparverius*), and Cooper's hawk (*Accipiter cooperii*), are also found in the Southwest program area. In the plateau regions of Arizona and New Mexico, common birds include the red-shafted flicker (*Colaptes auratus*), pinyon jay (*Gymnorhinus cyanocephalus*), bushtit (*Psaltriparus minimus*), and plain titmouse (*Parus inornatus*).

Reptiles such as the Gila monster (*Heloderma suspectum*), lesser earless lizards (*Holbrookia maculata*) and collared lizards (*Crotaphytus collaris*), glossy snake (*Arizona elegans*), and pine-gopher snake (*Pituophis melanoleucus*) are found in the plateau regions. The Texas horned lizard

(*Phrynosoma cornutum*), Western whiptail lizard (*Cnemidophorus tigris*), Western diamondback rattlesnake (*Crotalus atrox*), longnose snake (*Rhinocheilus lecontei*), and Western blind snake (*Leptotyphlops humilis*) can be found in the desert areas. The Western skink (*Eumeces skiltonianus*), bluntnose leopard lizard (*Gambelia silus*), Western whiptail (*Cnemidophorus tigris*), and coachwhip (*Masticophis flagellum*) inhabit the San Joaquin Valley of California.

### Domestic Animals

Livestock and livestock products are important components of the agricultural income of each State in all of the program areas. Beef cattle and other livestock are raised in the Southeast program area. Hogs, chickens, and turkeys also are common in States in the Southeast program area. In addition, sheep and mules are raised in Tennessee. The South Central and Southwest regions devote much land to raising beef cattle. Poultry is significant in California. Sheep are also raised in Arizona and New Mexico.

Beef cattle breeds found in the program areas include the Aberdeen-Angus, Hereford, Shorthorn, and Santa Gertrudis. Common dairy cows include the Holstein-Friesian and Jersey cows, while Devon and Red Poll are used for dairy products and beef. Chickens, such as White Leghorn and its hybrids, are used for egg production; the White Plymouth Rock is a common broiler chicken.

Dogs and cats are common farm pets in all program areas.

## Terrestrial Invertebrates

### Cotton Arthropod Complex

Cotton fields are inhabited by a large number of species of insects, spiders, mites, and other arthropods that are referred to collectively as the cotton arthropod complex (Phillips et al., 1980; Reynolds et al., 1982). Very few of these species are economically important pests; most are beneficial organisms, such as predators and parasites, that aid in the natural suppression of potential pest populations (Newsom and Brazzel, 1968; Phillips et al., 1980; Reynolds et al., 1982; Ables et al., 1983).

Faunal surveys indicate that approximately 600 species of beneficial predaceous and parasitic arthropods inhabit cotton fields in Arkansas, for example, and approximately 300 beneficial species have been recorded in California (Whitcomb and Bell, 1964; Van den Bosch and Hagen, 1966). In contrast, approximately 100 arthropod species are known to attack the cotton crop within the United States as a whole (Newsom and Brazzel, 1968; Reynolds et al., 1982). Of these potential pests, approximately 24 species are thought to cause economically significant losses in production. Roughly 80 percent of the economic losses that occur are thought to be caused by a small number of key pest species present in each principal cotton-producing region (Newsom and Brazzel, 1968; Reynolds et al., 1982; Ables et al., 1983).

Key pests are species with population sizes that are not reliably controlled by biological or environmental factors under present production methods and that exceed economic thresholds during most years. These are the species that must be suppressed to allow profitable cotton production (Reynolds et al., 1982). The key pests found in principal cotton-growing regions within the United States are described below (Phillips et al., 1980; Reynolds et al., 1982):

- In the humid regions of the Southeast Coastal and Mississippi Delta: the boll weevil (*Anthonomus grandis* Boheman), tarnished plant bugs (*Lygus* spp.), bollworm (*Heliothis zea* (Boddie)), and tobacco budworm (*Heliothis virescens* (Fabricius)).

- In the semi-arid South Central region: the boll weevil, cotton fleahopper (*Pseudatomoscelis seriatus* (Reuter)), bollworm, and tobacco budworm.

- In the irrigated deserts of the Southwest: the boll weevil, the pink bollworm (*Pectinophora gossypiella* (Saunders)), lygus bug (*Lygus hesperus* Knight), spider mites (*Tetranychus* spp.), bollworm, and tobacco budworm.

Of these key pests, the boll weevil and pink bollworm are thought to cause the most consistent and serious problems for U.S. cotton production. Members of the *Heliothis* complex (the bollworm and tobacco budworm) have become particularly destructive in recent years, and occasionally they cause more damage than the boll weevil in the Southern States (NRC, 1981; Reynolds et al., 1982). The status of the *Heliothis* species as key pests is a matter of some debate, however, and some entomologists would classify these insects as secondary pests, the outbreaks of which are caused primarily by insecticide use (Reynolds et al., 1982).

***Pink Bollworm.*** The pink bollworm, *Pectinophora gossypiella* (Saunders), a native of Asia, is thought to be the most serious worldwide cotton pest (Newsom and Brazzel, 1968). It appeared in the United States in 1917 and spread eastward from Texas into Oklahoma, Louisiana, Arkansas, Florida, and southern Georgia. Populations also became established in New Mexico, Arizona, Nevada, and southern California. Strict regulatory action involving mandatory stalk destruction during 1917-21 eliminated populations in eastern Texas, western Louisiana, northern Florida, and southern Georgia (Newsom and Brazzel, 1968). A nonplanting zone was used to eliminate a Georgia population during 1933-35 (NRC, 1981). The insect became reestablished in Texas during 1952 and has remained established throughout the Southwest since first being introduced (Newsom and Brazzel, 1968).

The pink bollworm is reported to feed on at least 39 plant species in the United States (Pfadt, 1962). A generation can be completed in 25 to 30 days during summer, with as many as six generations occurring during a single growing season. Larvae developing during late summer and fall produce a particularly thick cocoon and enter a state of

dormancy, passing the winter within the cotton boll or other fruit in which they have been feeding. In warm, humid areas, the survival of dormant larvae is highest in bolls that remain attached to standing plants or that fall to the soil surface. Few larvae survive if buried in soil, and temperatures below 15°F kill larvae in bolls that remain on standing plants (Pfadt, 1962).

***Plant Bugs.*** Several species of plant bugs are important pests in different portions of the Cotton Belt. Lygus bugs, particularly *Lygus hesperus* Knight, are major pests in the irrigated western deserts. The cotton fleahopper (*Pseudoatomoscelis seriatus* (Reuter)) is an important pest in portions of Texas and Oklahoma. The tarnished plant bug (*Lygus lineolaris* (Palisot de Bauvois)) occurs in the Mississippi Delta region.

These insects attack a wide variety of wild and cultivated plants, using their sucking mouthparts to extract plant juices from stems, flowers, and fruits. Feeding by plant bugs causes damage to cotton plants in two ways: shedding of small flower buds (squares) and abnormal development of stems and leaves (Pfadt, 1962). Some studies suggest that cotton plants can tolerate appreciable amounts of plant bug feeding before experiencing economically significant reductions in yield (Reynolds et al., 1982); however, this may not be true for the Mississippi Delta region (according to a personal communication with Jimmy Pendergrass, 1989).

***Bollworm and Tobacco Budworm.*** The bollworm (*Heliothis zea* (Boddie)) and tobacco budworm (*Heliothis virescens* (Fabricius)) (Lepidoptera: Noctuidae) also feed on a variety of wild and cultivated plants. Both species produce several generations during each growing season, requiring approximately 30 days per generation during summer in the Southern United States. Damage to the cotton crop is produced by the larvae, which feed preferentially on developing squares and bolls. *Heliothis* populations often increase to high densities on other crops (for example, *Heliothis zea* (Boddie) on corn, *Heliothis virescens* (Fabricius) on tobacco) and invade cotton fields during the middle or later stages of the growing season. Smaller populations are often controlled below economically damaging levels by predators, parasites, and pathogens.

However, in areas where insecticide treatments are used to suppress key pests such as the boll weevil, pink bollworm, or mirid plant bug, the insecticide-induced destruction of natural enemies commonly leads to outbreaks of *Heliothis* spp. (Newsom and Brazzel, 1968; Bottrell and Adkisson, 1977; Phillips et al., 1980; Reynolds et al., 1982). Both species of *Heliothis* have become resistant to a number of widely used insecticides, have become particularly destructive pests in recent years, and have frequently caused greater damage than the boll weevil in the southeastern and Delta States (NRC, 1981; Reynolds et al., 1982).

***Other Pests.*** A number of other arthropod species feed on cotton plants and occasionally increase to damaging levels. Examples include

the beet armyworm (*Spodoptera exigua* (Hübner), cabbage looper (*Trichoplusia ni* (Hübner), salt marsh caterpillar (*Estigmene acrea* (Drury)), cotton leaf perforator (*Bucculatrix thurberiella* Busck), cotton aphid (*Aphis gossypii* Glover), whiteflies (Aleyrodidae), and spider mites (Tetranychidae). In some cases, damaging outbreaks of these pests are caused by chance weather events that enhance the growth rates of pest populations or weaken the effect of predators, parasites, and pathogens. Outbreaks also are caused by changes in agronomic practices, such as the adoption of cotton varieties with increased susceptibility to particular pests.

Outbreaks of these occasional or potential pests can also be caused inadvertently by insecticide treatments applied for the suppression of key pests, such as the boll weevil, pink bollworm, or lygus bugs. Insecticide treatments tend to eliminate populations of predatory and parasitic insects and result in damaging outbreaks of secondary pests (Bottrell and Adkisson, 1977; Metcalf, 1980; Phillips et al., 1980; Reynolds et al., 1982). Insecticide-induced outbreaks of secondary pests have been documented not only in cotton-growing areas of the United States, but also in Australia, Egypt, El Salvador, Guatemala, Mexico, Nicaragua, and Peru (Bottrell and Adkisson, 1977; Metcalf, 1980).

***Beneficial Species.*** Most arthropod species that occur in cotton fields are beneficial. Common predators that occur throughout most areas of the Cotton Belt include green lacewings (*Chrysopa* spp.); brown lacewings (*Hemerobius* spp.); minute pirate bugs (*Orius* spp.); big-eyed bugs (*Geocoris* spp.); damsel bugs (*Nabis* spp.); lady beetles (*Coccinella* and *Hippodamia* spp.); hover flies (*Syrphus* spp.); and certain predaceous thrips (Thysanopterae), mites (Acarinae), and spiders (Araneidae). Beneficial parasitic species come primarily from the insect orders Hymenoptera (families Ichneumonidae and Braconidae and superfamily Chalcidoidea) and Diptera (families Techinidae and Sarcophagidae). Detailed species lists of beneficial predaceous and parasitic groups have been provided by Whitcomb and Bell (1964) and Van den Bosch and Hagen (1966).

In general, pests of foreign origin, such as the boll weevil, are attacked by fewer beneficial species than pests that are native to the United States. At present, approximately 50 species of predators and parasites are known to attack the boll weevil in this country (Ables et al., 1983). Additional species in Central America may be candidates for introduction in the future (Phillips et al., 1980; Ables et al., 1983). Of the beneficial species in the United States, none appears to provide reliable beltwide control under current cotton-production methods (Reynolds et al., 1982).

### Other Terrestrial Invertebrates

Numerous bugs, flies, crickets, ants, worms, grasshoppers, butterflies, and other invertebrates are found throughout the program areas. Bees, butterflies, and other pollinators are widespread and crucial for the propagation of numerous crops and other plant species. Honey bees

(*Apis mellifera*) are especially common and are important crop pollinators. Commercial beekeeping for agriculture and honey is a significant small industry in the United States.

A biological assessment has been prepared to determine any effects on listed and proposed endangered and threatened invertebrate species that may be present in program areas. A summary of the biological assessment can be found in appendix H.

***Southeast Coastal and Delta Program Areas.*** Terrestrial invertebrates characteristic of the Southeast program area include the Hercules beetle (*Dynastes titylus*), scorpionfly (*Panorpa confusa*), sticktight flea (*Echidnophaga gallinacea*), and click beetle (*Elateridae* spp). Butterflies, such as the great purple hairstreak (*Atlideshalesus*), Diana (*Speyeria diana*), zebra (*Heliconius charitonius*), and white-m hairstreak (*Parrhasius m-album*), and the fire ant (*Solenopis* spp.) also occur here.

***South Central Program Area.*** Invertebrates in this program area include the green valley grasshopper (*Schistocerca shoshone*), fire ant (*Solenopis* spp.), carpenter ant (*Camponotus festinatus*), California mantis (*Stagmomantis california*), and broad-winged katydid (*Microcentrum rhombifolium*). Butterflies and moths found in this area include the greasewood moth (*Agapema galbina*), bella moth (*Utetheisa bella*), Acmon blue (*Plebejus acmon*), and monarch butterfly (*Danaus plexippus*).

***Southwest Program Area.*** Terrestrial invertebrates found only in this program area include the panther spotted grasshopper (*Poecilotettix pantherina*), desert skunk beetle (*Eleodes armata*), white grub wasp (*Triscolia ardens*), and harvester ant (*Pogono-myrmex barbatus*). Butterflies and moths include Barnes' tiger moth (*Ozadamia barnesii*), Lorquin's admiral (*Limentis lorquini*), western sister (*Adelpha bredowii*), chalcedona checkerspot (*Euphydryas chalcedona*), and sleepy orange butterfly (*Eurema nicippe*). Other invertebrates found in this area include the desert tarantula (*Aphonopelma chalcodes*) and the centruroides scorpion (*Centruroides* spp.).

## Aquatic Species

### Aquatic Vertebrates

The numerous natural and manmade water bodies throughout the program area have diverse aquatic vertebrate life. In all program States, popular game fish, such as largemouth bass, smallmouth bass, yellow bass, and bluegill, as well as various suckers and minnows, are present (Walden, 1964; Thompson, 1985). In addition to fish, various frogs, salamanders, turtles, and snakes inhabit the lakes, ponds, rivers, and streams of the program areas. A biological assessment has been prepared to determine any effects on listed and proposed endangered and threatened aquatic species. A summary of the biological assessment can be found in appendix H.

***Southeast Program Area.*** Fish found in natural water bodies of the Coastal subarea include the redbreast sunfish (*Lepomis auritus*), pumpkinseed (*Lepomis gibbosus*), bluespotted sunfish (*Enneacanthus

gloriosus), and tesselated darter (*Etheostoma olmstedi*). Fish in the Delta subarea include the river darter (*Percina shumardi*), shortnose gar (*Lepisosteus platostomus*), blackside darter (*Percina maculata*), and bluntnose minnow (*Pimephales notatus*). In both subareas, chain pickerel (*Esox niger*), black crappie (*Pomoxis nigromaculatus*), and channel darter (*Percina copelandi*) can be found.

In cotton-producing areas of the Southeast, farm ponds are occasionally stocked for recreational fishing with blue catfish (*Ictalurus furcatus*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and smallmouth bass (*Micropterus dolomieu*). Fathead minnows (*Pimephales promelas*) are stocked for forage. In the Delta subarea, fish farming is an important industry. In Mississippi alone, 90,000 acres are devoted to fish production, with more than 40 percent of the fish ponds located near cotton fields. Fish stocked for commercial sale include channel catfish (*Ictalurus punctatus*) and blue catfish (*Ictalurus furcatus*).

Various waterdogs (*Necturus* spp.), newts (*Notopthalmus* spp.), and dusky salamanders (*Desmognathus* spp.) are found in streams and ditches along the Coastal Plain and Mississippi Valley in the Southeast program area. Snapping turtles (*Chelydra* spp.) and mud turtles (*Kinosternon* spp.) can also be found on the Coastal Plain. The cottonmouth (*Agkistrodon piscivorous*), the only poisonous aquatic snake in this area, is found as far west as central Texas. Many other nonpoisonous aquatic snakes (*Nerodia* spp.) are found in the Southeast program area (Conant, 1958).

***South Central Program Area.*** Fish that are generally restricted to the South Central program area include the roundnose minnow (*Dionda episcopa*), Mexican tetra (*Astyanax mexicanus*), and sandshiner (*Notropis stramineus*) (Thompson, 1985; Boschung et al., 1983). The gizzard shad (*Dorosoma cepedianum*), white bass (*Morone chrysops*), longnose gar (*Lepisosteus osseus*), redbreast sunfish (*Lepomis auritus*), and mosquito fish (*Gambusia affinis*) also are found in the South Central program area.

In areas such as the Blacklands of Texas, farm ponds often serve as watering holes for livestock. Such ponds are rarer in the drier High Plains where much of the South Central area's cotton is grown. Channel catfish (*Ictalurus punctatus*) is the stockfish of choice for recreational fishing in this program area, although flathead catfish (*Pylodictis olivaris*), bluegill (*Lepomis macrochirus*), and blue catfish (*Ictalurus furcatus*) are also stocked.

The bullfrog (*Rana catesbeiana*), Rio Grande leopard frog (*Rana pipiens berlandieri*), spotted chorus frog (*Pseudacris clarki*), mud turtle, and snapping turtle are other aquatic vertebrates found in this region (Conant, 1958).

***Southwest Program Area.*** In natural water bodies of the Southwest program area, fish include rainbow trout (*Salmo gairdneri*), mosquito fish (*Gambusia affinis*), black bullhead catfish (*Ictalurus melas*), fathead minnow (*Pimephales promelas*), golden shiner (*Notemigonus crysoleucas*),

and speckled dace (*Rhinichthys osculus*). Desert pupfish (*Cyprinodon macularius*) are restricted to desert streams (Thompson, 1985; Boschung et al., 1983; MacMahon, 1985).

In the arid Southwest, irrigation ditches replace farm ponds for watering livestock. Numerous fish, including mosquito fish and channel catfish, can be found in ditches near cotton fields.

Most reptiles and amphibians here are terrestrial, although aquatic species, such as the bullfrog (*Rana catesbeiana*) and the Rio Grande leopard frog (*Rana pipiens berlandieri*), can also be found. Other reptiles and amphibians, such as the tiger salamander (*Ambystoma tigrinum*), occur only where there is water in which to breed (Conant, 1958; MacMahon, 1985).

### Aquatic Invertebrates

Diverse aquatic invertebrates and terrestrial invertebrate larvae inhabit nonpolluted water bodies in all program areas. A variety of worms (Oligochaeta), leeches (Hirudinea), snails (Gastropoda), mussels (Pelecypoda), crayfish, and shrimp (Crustacea) populates the inland waters and Gulf Coast shores, feeding on detritus, plants, and smaller invertebrates such as copepods (for example, *Calanoida* spp.), rotifers (for example, *Keratella* spp.), and cladocerans (for example, *Daphnia* spp.). These small invertebrates, which make up the zooplankton, are close to the bottom of the aquatic food chain and thus directly or indirectly support all larger aquatic life, including economically important species. Numerous shrimp hatcheries are located on the Texas Gulf Coast. Shrimp are harvested for both commercial and research purposes. Freshwater crayfish are collected from inland waters of the Southeast program area for human consumption.

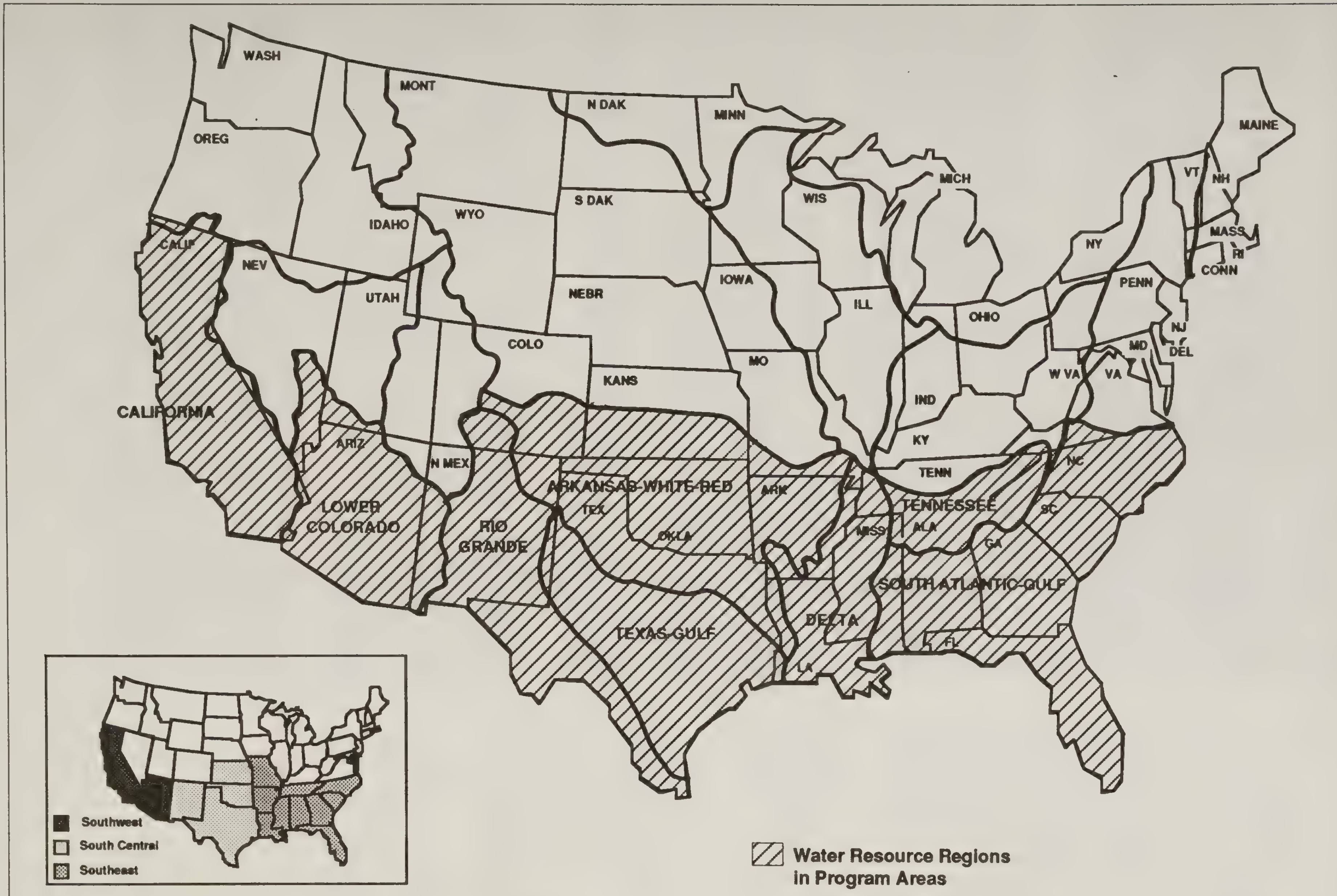
The mayfly (Ephemeroptera), dragonfly (Odonata), and stonefly (Plecoptera) are closely associated with water, and aquatic larval and nymph forms of these and other insect species in both benthic and lentic communities are an important food source for many freshwater fish. A number of flies (Diptera) and mosquitoes (Culicidae) also depend on water for part of their life cycle. Truly aquatic insects include giant waterbugs (Belostomidae), water scorpions (Nepidae), and water beetles (Haliplidae) (Klots, 1966; Borror and White, 1970).

## Surface Water, Groundwater, and Water Quality

Aquatic resources are linked to river basins and watersheds, which the U.S. Geological Survey (USGS) calls water resource regions. Therefore, the Cotton Belt's aquatic resources are described by program areas and are then further subdivided into the main water resource regions of each program area (fig. 3-9).

The Southeast program area contains the South Atlantic-Gulf water resource region, the Tennessee water resource region, and the Mississippi Delta water resource region. The South Central program area has the Texas Gulf, the Arkansas-White-Red, and the Rio Grande water resource regions. The Lower Colorado water resource region and the

## Figure 3-9. Water Resource Regions




Source: USGS 1982.

California water resource region are in the Southwest program area. Each water resource region is described in terms of its surface water, groundwater, and water quality.

The quality of surface water and groundwater resources in the Cotton Belt is affected by a wide range of human activities, as well as naturally occurring pollutants. Examples of water quality problems discussed in the water resource regions are pollutants from industry, landfills, mining, agricultural chemical use, and saltwater intrusion. Applications of herbicides to control weeds, fertilizer to improve soil quality, and pesticides to control agricultural pests are examples of agricultural practices that may affect water quality.

### Southeast Program Area

The Southeast program area is known for its slow-moving streams and farm ponds. Historically, cotton fields often were located close to water transportation systems for moving cotton to gins and markets. In addition, cotton fields were traditionally located in floodplains that contained more fertile soils that were easier to cultivate. Today, however, cotton fields are well dispersed throughout agricultural areas because of the development of train and truck transportation routes.

Pressures on land use in the Southeast program area generally are not intense. Therefore, native or scrub vegetation usually buffers streams from cotton fields and other tilled areas. However, farm ponds usually are located near or within fields of cotton and other crops, or in pastures used for grazing by domestic animals. Farm ponds generally do not have physical buffers that protect them from surface water runoff.

Cotton is grown in all three water resource regions of the Southeast program area: the South Atlantic-Gulf region, the Tennessee region, and the Delta region (fig. 3-9).

### South Atlantic-Gulf

*Surface Water.* Slow-moving rivers and streams are abundant throughout this water resource region. The largest of these rivers—the Tombigbee, the Alabama, the Mobile, and the Apalachicola—discharge into the Gulf of Mexico (USGS, 1984), with an average annual stream flow of 207 billion gallons per day (USGS, 1982) and an offstream consumptive use of 5.1 billion gallons per day (table 3-1). Other significant rivers in this region include the Tallapoosa River and the Coosa River.

Three types of natural lakes occur in this region: Carolina bays (oval-shaped swampy areas) in the Carolinas and Georgia, oxbow lakes (crescent-shaped lakes formed in abandoned river channels), and solution ponds (ponds formed by the erosion of limestone) in Florida and along the Gulf Coast (USGS, 1982). Numerous farm ponds and large shallow reservoirs throughout the region are often used for irrigation (USGS, 1985). Smith Lake and the Tallapoosa basin are examples of reservoirs created by dams.

**Table 3-1. Water Resource Summary**

| Water resource region | Average annual stream outflow (billions of gallons/day) | Estimated percent of water supplied to public by groundwater resources | Source of water quality problems |
|---|---|---|---|
| **Southeast:** | | | |
| South Atlantic-Gulf | 207.0 | 52 | Mining, landfills, saltwater intrusion, land subsidence, industry, agricultural chemical use |
| Tennessee | 42.9 | 20 | Agricultural chemical use, industrial and municipal wastes, lake eutrophication |
| Mississippi Delta— | | | |
| Lower | 433.0 | 66 | Saltwater intrusion, land subsidence |
| Upper | 77.6 | 62 | Saltwater intrustion, industry |
| **South Central:** | | | |
| Texas Gulf | 30.7 | 43 | Oil and gas production, natural saline conditions |
| Arkansas-White-Red Area | 56.3 | 27 | Natural saline conditions |
| Rio Grande Area | 1.8 | 65 | Natural saline conditions |
| **Southwest:** | | | |
| Lower Colorado | 7.2 | 55 | Agricultural chemical use, industry |
| California | 62.8 | 70 | Agricultural chemical use, industry, land subsidence |

Sources: USGS, 1982, 1985, 1988.

Wetlands in floodplains are a dominant feature in Florida. The Okefenokee Swamp, a wildlife refuge and wilderness area, is an outstanding wetland in southeastern Georgia.

*Groundwater.* This region has one of the most productive groundwater networks of both unconfined and confined aquifers in the United States (Fetter, 1980). The most highly productive aquifers of this region are composed of sands, sandstone, dolomites, and limestones (USGS, 1982). The higher elevations of the Coastal Plain consist of consolidated rock aquifers, with minimal water available from joints and fractures (USGS, 1982). The base flow of streams is derived from groundwater discharge, conservatively estimated at 78 billion gallons per day (USGS, 1982). Groundwater flow is seaward, with local gradients affecting the pressure and quality of the groundwater resources (USGS, 1982).

Groundwater supplies 52 percent of all water used by the public in this region, and approximately 54 percent of the water used for irrigation (USGS, 1988) (table 3-1). In many areas, large groundwater withdrawals significantly affect water levels in swamps and lakes and the flow of streams and springs (USGS, 1982).

*Water Quality.* The water quality of streams and reservoirs in the Southeast program area is generally good, although simple treatment is required for excessive iron and other corrosives. Pollutants in this region come from agricultural chemical use, mining, landfills, saltwater intrusion, land subsidence, and industry. Surface waters are not extensively polluted by manmade waste (USGS, 1985; USGS, 1982).

### Tennessee Water Resource Region

*Surface Water.* The Tennessee water resource region has abundant surface water resources. Its principal river, the Tennessee River, is highly developed, with reservoirs and dams for flood control and electric power generation. The average annual stream outflow in the region is 42.9 billion gallons per day, with 0.4 billion gallons per day used for offstream consumption (USGS, 1985) (table 3-1). Surface water is the primary source of water for offstream consumption.

*Groundwater.* Groundwater aquifers of carbonate, fractured noncarbonate rock, and unconsolidated material cover 41,000 square miles of this region, but they are not fully recognized as a source of water because of the abundant surface water (USGS, 1982). An average of 20 percent of the water used by the public in this region comes from groundwater (USGS, 1988) (table 3-1).

More uniform production is found in the unconsolidated aquifers in the western portion of this region. Water yields vary in consolidated aquifers, depending on the size and depth of the solution openings caused by the erosion of carbonate rock or fractures; most groundwater is within 300 feet of the surface (USGS, 1982).

*Water Quality.* Surface water quality in this region is generally suitable for most uses. Pollution sources are nonpoint-source runoff from farmland, industrial, and municipal wastes; lake eutrophication; and low-dissolved oxygen concentrations in reservoir releases (USGS, 1982). Groundwater quality is generally good; chemical and physical properties are usually within EPA-recommended limits (USGS, 1982).

### Delta Water Resource Region

*Surface Water.* Numerous slow-moving rivers and streams exist in this water resource region, with the Mississippi River being the largest. Average annual streamflow on the Mississippi River varies from 433 billion gallons per day near the Gulf of Mexico to 77.6 billion gallons per day upstream (USGS, 1985). Rivers that discharge into the Mississippi River include the White, Arkansas, Red, and Atchafalaya. Marshes, swamps, and lakes are common (Bailey, 1980). Thermoelectric power generation and industrial use account for most of the surface water withdrawals; withdrawals for irrigation are not significant.

Numerous reservoirs are used for flood control and recreation (USGS, 1985). Twenty-nine controlled surface water reservoirs have a capacity of 5,000 acre-feet or more and a combined storage of about 10 million acre-feet (USGS, 1982).

*Groundwater.* Groundwater is abundant in the Mississippi Delta region. Only one-third of groundwater reserves, estimated at 844 million cubic feet, is being used (USGS, 1985). An extensive system of aquifers consists of mostly unconsolidated sand and gravel aquifers of the Tertiary and Quaternary Ages. The Mississippi River Valley alluvial aquifer is the most productive and extensive aquifer along the lower Mississippi River.

In this water resource region, groundwater supplies 63 percent of water used by the public (USGS, 1988).

*Water Quality.* The quality of groundwater in this region is generally good, but it varies from aquifer to aquifer. Typically, the groundwater has a total dissolved solids (TDS) concentration of less than 1,000 mg/L (USGS, 1982). Southwestern Louisiana is the exception, where all the groundwater is saline to varying degrees (USGS, 1982).

The water quality of streams and reservoirs in this area is generally good. Except for the Mississippi River, surface waters are not extensively polluted by manmade waste (USGS 1985). Pollution from agricultural and industrial practices occurs in localized areas.

## South Central Program Area

The South Central program area is generally composed of land that receives less rainfall than the Southeast program area, and approximately 25 to 30 percent of the cotton acreage is irrigated. Cotton fields are less likely to have thickly vegetated buffers between them and neighboring streams or irrigation ditches.

The hydrologic characteristics of this program area vary dramatically, creating three distinct water resource regions: the Texas Gulf region, the Arkansas-White-Red Rivers region, and the Rio Grande region (fig. 3-9).

### Texas Gulf Water Resource Region

***Surface Water.*** Ample surface water provides 48 percent of this water resource region's irrigation needs (USGS, 1984). Three principal river basins exist in the Texas Gulf region: the Sabine-Neches-Trinity-San Jacinto, the Brazos-Colorado, and the Lavaca-Guadalupe-Nueces. Average annual stream outflow is 30.7 billion gallons per day (USGS, 1985) (table 3-1). Lake Texana, a main reservoir on the Lavaca River in southwest Texas, has a storage capacity of 52,500 million gallons (USGS, 1985).

Three principal reservoirs on the Nueces are used for municipal supplies and irrigation (USGS, 1985). The Guadalupe and Nueces Rivers are of particular concern because most of their tributaries cross the permeable fault zone near the Edwards aquifer (USGS, 1985).

In the Brazos-Colorado River Basin, agriculture is the dominant land use. The Brazos River starts in the High Plains of New Mexico and discharges into the Gulf of Mexico, depositing an estimated 104,250 tons of eroded topsoil at the river's mouth (USGS, 1984).

The Colorado River of Texas (not to be confused with the Colorado River of the Southwest) flows from the High Plains of New Mexico and drains entirely in Texas. Most of its principal tributaries are perennially flowing streams fed by groundwater (USGS, 1985). The Colorado River of Texas accounts for 73 percent of municipal water use in this region (USGS, 1984). Numerous reservoirs are used primarily for flood control and water supply (USGS, 1985). Other lakes are used for hydroelectric-power generation and recreation.

***Groundwater.*** Groundwater provides 43 percent of public freshwater needs in this region (USGS, 1988) (table 3-1). Significant groundwater reservoirs underlie four-fifths of the Texas Gulf region (USGS, 1985). Significant aquifers include the Trinity, Ogallala, Edwards, and Gulf Coast aquifers.

The Trinity aquifer of sand, shale, and limestone is one of this region's important groundwater reservoirs. This aquifer underlies 20,000 square miles in central Texas. The Ogallala aquifer underlies about 19,000 square miles of the High Plains of Texas. The Edwards aquifer, which occupies 2,500 square miles along the Balcones Escarpment, is recharged primarily by the Guadalupe and Nueces Rivers (USGS, 1986). The Gulf Coast aquifer extends inland from the coast for about 90 to 120 miles.

***Water Quality.*** Surface water quality in this region is significantly affected by natural events and human activities. Concentrations of

sodium chloride from salt springs and deposits can make river and reservoir water unfit for most uses (Rawson, 1974). Oil and gas exploration and production activities are other potential sources of pollution. Pollution from agricultural chemicals is not considered a major problem in the Gulf (USGS, 1982), although use of agricultural chemicals close to surface water could have a significant impact on the quality of groundwater.

Chemical infiltration of the rivers discharging into the Gulf also could affect the Gulf's commercial and sport fishing, navigation (because of the increase in aquatic vegetation), shell dredging, and recreation activities (USGS, 1985). The primary aquifers of the region now contain concentrations of less than 3,000 mg/L for dissolved solids (USGS, 1982).

### Arkansas-White-Red Rivers Water Resource Region

The Arkansas-White-Red Rivers water resource region includes the cotton-growing regions of northern Texas, Oklahoma, Arkansas, and the northeast corner of New Mexico (fig. 3-9).

***Surface Water.*** The annual stream outflow in this area is 56.3 billion gallons per day, of which an estimated 9.6 billion gallons per day is withdrawn for use (USGS, 1985). Surface water in this region varies from the eastern portion, which has a water surplus, to the western section, which is deficient in water (USGS, 1982). The three largest rivers in this water resource area are the Arkansas, the White, and the Red. The Canadian River also runs through this region.

Both the Red River and the eastern section of the Canadian River drain in the northern section of Texas (USGS, 1985). Irrigation is the dominant use of water from the Red River. Lake Texoma, found in northern Texas, is the largest lake in the State and is one of 22 adjacent reservoirs used primarily for flood control and hydroelectric-power generation (USGS, 1985). The Canadian River's eastern section is not used for public water supply because of high salinity, inadequate dams, and inconsistent supply (USGS, 1985).

The Canadian River's western section also drains in the Texas High Plains (USGS, 1985). Its basin contains two reservoirs, of which Lake Meredith is the largest. It supplies 11 cities with water for municipal and manufacturing uses.

The Arkansas River flows southeasterly through Oklahoma (USGS, 1985). This area contains seven major reservoirs that have a total storage capacity of 789,000 million gallons (USGS, 1982). Creeks and lakes are abundant throughout this region (USGS, 1985).

*Groundwater.* Twenty-seven percent of water used by the public in the Arkansas-White-Red region is supplied by groundwater (USGS, 1988) (table 3-1). Groundwater accounts for 78 percent of water used for agricultural irrigation. Most of the aquifers in this region consist of alluvial carbonate rocks, gypsum, and sandstone (USGS, 1982). The groundwater reserves are estimated at 2 billion acre-feet.

Sand and sandstone aquifers exist in the High Plains and range in thickness from 100 to 500 feet (USGS, 1982). Carbonate and gypsum aquifers exist principally in Arkansas and Missouri. These aquifers range in thickness from 50 to 1,500 feet, with the depth to water ranging from 30 to 450 feet (USGS, 1982). Pollution is a problem in these aquifers because pollutants can enter in large quantities and be transported rapidly throughout the system (USGS, 1982).

*Water Quality.* Surface water quality generally is poor in the Arkansas-White-Red Rivers water resource region. The Red River has a naturally high concentration of chloride, which makes the water unsuitable for municipal and irrigation use (USGS, 1985); concentrations of dissolved solids can exceed 25,000 mg/L in the Red River (USGS, 1985).

Naturally occurring salt deposits also render much of the Arkansas River unsuitable for municipal and irrigation purposes. Other rivers in the region have similar surface water problems, as well as an inconsistent supply of surface water (USGS, 1985).

Groundwater quality generally is good throughout this region, but it varies according to aquifer type and quality of water entering the aquifer. Carbonate and gypsum aquifers are more subject to pollution than other aquifers in this area because they are cavernous (USGS, 1985). Sand and sandstone aquifers are also highly susceptible to pollution.

### Rio Grande Water Resource Region

*Surface Water.* The Rio Grande River is the principal perennial river in this water resource region and the fourth longest river in the United States (USGS, 1985). It forms the boundary between the United States and Mexico. The Pecos River, its main tributary, drains partly in Texas. Only 5 to 8 percent of the surface water in the Rio Grande water resource region is used for irrigation (USGS, 1984). Reservoirs provide the primary source of surface water for irrigation. Two of the largest are the International Falcon Reservoir and the International Amistad Reservoir; these particular reservoirs are used primarily for conservation, storage, and flood control (USGS, 1985). Very few naturally occurring lakes are found in this region.

*Groundwater.* Most water needs in this region are met by groundwater withdrawals (USGS, 1985). Groundwater reservoirs contain approximately 5,800 million acre-feet of fresh to slightly saline water. In 1985, 18 million acre-feet of groundwater was withdrawn (65 percent of the water supplied to public) (USGS, 1988) (table 3-1). Irrigation was the

primary use (74 percent) of the groundwater withdrawn in 1985 (USGS, 1988).

The region's aquifers are typically thick deposits of unconsolidated valley fill. The largest groundwater reserves are in the San Luis Valley and Albuquerque aquifers (USGS, 1982). Consolidated sedimentary rocks (sandstone and limestone) underlie a major section of the cotton-growing areas of this region.

***Water Quality.*** Surface water quality in the Rio Grande water resource region ranges from poor to good. Concentrations of total dissolved solids range from approximately 300 to 500 mg/L. In the spring, water is released from reservoirs in New Mexico to augment stream flows, resulting in marked improvement of water quality in that season (USGS, 1985). Saline water runs into the Rio Grande River by way of the Pecos River.

The groundwater quality in this region also varies. The quality of water in the shallow valley-fill aquifers has been significantly affected by the recharge of water containing fertilizers from irrigated fields.

## Southwest Program Area

The Southwest program area is generally arid and dependent on irrigation to produce cotton. Therefore, cotton fields are located close to irrigation ditches. Infrequent rains can cause erosion of topsoil and leaching of pesticides into irrigation ditches and streams.

Cotton fields of the Southwest program area can be found in the Lower Colorado and the California water resource regions (table 3-1).

### Lower Colorado Water Resource Region

***Surface Water.*** Surface water is a limited resource in Arizona because of its arid climate and high evaporation rate. The average annual stream outflow in this region is 2.5 billion gallons per day, which meets only 35 percent of the needs of the State.

The Colorado and the Gila Rivers are major rivers. Nearly all the streams are tributaries of the Colorado River (USGS, 1982). The Colorado River is divided into upper and lower river basins, with the principal cotton-growing areas of Arizona incorporated in the lower Colorado River Basin. The Colorado River flows southwesterly through the Grand Canyon into New Mexico, discharging into the Gulf of California (USGS, 1985). Dams occur frequently on the Colorado River and divert water from the river for irrigation and municipal uses (USGS, 1985). The Gila River, which flows westerly across the southern part of Arizona, is dammed for irrigation, flood control, and power generation (USGS, 1985).

An extensive network of dams has created large lakes, including Lakes Mohave and Havasu, and the largest reservoir in the United States, Lake Mead. Total storage for these reservoirs is approximately

59.2 million acre-feet (USGS, 1985). Reservoirs also have been created by Coolidge Dam, Gillespie Dam, and Painted Rock Dam (USGS, 1985).

*Groundwater.* Over one-half of the water needs of this region are met by groundwater withdrawals (USGS, 1988) (table 3-1). About 1.5 billion acre-feet of groundwater is stored in aquifers in this region. Groundwater is withdrawn faster than it is replenished, and accounts for 78 percent of the water used for irrigation. Water levels are generally 200 to 500 feet below land surface (USGS, 1982).

The aquifers of this region's lower elevations contain thick sediments of poorly sorted clay, silt, sand, and gravel (USGS, 1982). More permeable sand and gravel beds in higher elevations of the region are the most extensively developed areas of groundwater (USGS, 1982).

*Water Quality.* The water quality of both surface and groundwater is generally good (USGS, 1982). The dissolved solid concentrations range from less than 100 mg/L to more than 100,000 mg/L (USGS, 1982). Because of the generally unconfined aquifer types and the high water table, the potential for groundwater quality degradation from using agricultural chemicals is considered a minor problem in this area. Industry is considered a significant source of pollution in this area (USGS, 1982).

### California Water Resource Region

*Surface Water.* The average annual stream outflow in this region is 62.8 billion gallons per day, of which 25 billion gallons per day is withdrawn for use (USGS, 1985). Surface water resources supply approximately 60 percent of freshwater needs (USGS, 1985). An extensive reservoir network in California includes 260 reservoirs having a capacity of more than 5,000 acre-feet and 40 reservoirs with the capacity of more than 200,000 acre-feet (USGS, 1985). Most of California's cotton is grown in the San Joaquin Valley subregion and the Tulare-Buena Vista Lakes subregion.

Along the San Joaquin River, stream flow is influenced by mountain snowfields, reservoirs, interbasin transfer, groundwater pumping, irrigation return flow, and artificial recharge (USGS, 1985). Runoff comes primarily from the Sierra Nevada (USGS, 1985). The main reservoirs are Millerton Lake, with 169,000 million gallons of storage on the Mokelumne River; the Hetch Hetchy Reservoir, with 117,000 million gallons of storage on the Tuolumne River; and the San Luis Reservoir, with 664,000 million gallons of storage (USGS, 1982).

The California aqueducts, the Delta-Mendota Canal, and the Friant-Kern Canal, transport water from the San Joaquin River Basin into the extensively irrigated Tulare-Buena Vista Basin (USGS, 1985). The Tulare-Buena Vista Basin Lake is a closed basin with more than 1.4 million acres irrigated for cotton production (USGS, 1985). Rivers here include the Kings, the Kern, the Tule, and the Kaweah; and

principal reservoirs are Lake Isabella on the Kern and Pine Flat Lake on the Kings (USGS, 1985).

The Colorado River provides irrigation for the cotton-growing regions in southern California. The Salton Sea is close to cotton-growing areas in the Imperial Valley.

***Groundwater.*** Because of the semi-arid and arid climate in California, groundwater is an important resource. Most of this region's groundwater reservoirs exist in valley alluvial sediments. The largest of these reservoirs is in alluvial deposits in the California central valley, with an estimated capacity of 100 million acre-feet (USGS, 1985).

Water deficiency in this region can be supplemented by groundwater reservoirs used as repositories, where water can be stored with minimum loss by evaporation (USGS, 1985). Groundwater supplies 70 percent of the public water use and 25 percent of water used for irrigation (USGS, 1988).

***Water Quality.*** Because this region is extensively irrigated and cotton is grown in locations that have an average annual water deficiency, there is a high probability for contaminants to travel from one place to another (USGS, 1986).

Although agricultural and industrial activities have degraded surface water, it is generally suitable for most purposes. Streams that pass through irrigated areas receive organic substances and minerals leached from irrigated agricultural land (USGS, 1985). Similar impacts can occur on groundwater from water used for irrigation percolating to groundwater reservoirs. Saltwater intrusion and industrial pollution also have a significant effect on the quality of water in this region (USGS, 1985).

## Human Populations

### Demographics

The boll weevil control programs would affect farming areas that are sparsely populated, in comparison with the rest of the United States. In 1988 the farm population in Cotton Belt States ranged from 0.4 to 14.1 people per square mile, compared to 12.4 to 227.8 people per square mile for the total U.S. population. The average density for the program area regions was 5 people per square mile in agricultural areas, as compared with nearly 93 people per square mile total (table 3-2). If the population trends of the past 11 years continue (table 3-3), the number of individuals living in farming areas will decline over the span of the boll weevil control program.

Agricultural workers make up less than 10 percent of the total work force in Cotton Belt States, although in some cotton-producing counties, the agricultural work force may be as high as 20 percent.

Table 3-2. Population and Population Density of the Cotton Belt States, 1988

| Program area | Population (thousands) | | Population density[a] (per square mile) | |
|---|---|---|---|---|
| | Farm[b] | Total | Farm[c] | Total |
| **Southeast:** | 1,164 | 58,212 | 5.3 | 108.7 |
| Coastal— | 775 | 38,753 | 8.4 | 137.6 |
| Alabama | 82 | 4,102 | 5.0 | 80.8 |
| Georgia | 127 | 6,342 | 6.5 | 109.2 |
| South Carolina | 69 | 3,470 | 8.3 | 114.9 |
| North Carolina | 130 | 6,489 | 8.3 | 132.9 |
| Virginia | 120 | 6,015 | 8.5 | 151.5 |
| Florida | 247 | 12,335 | 14.1 | 227.8 |
| Delta— | 389 | 19,459 | 3.1 | 76.6 |
| Tennessee | 98 | 4,895 | 5.0 | 118.9 |
| Missouri | 103 | 5,141 | 2.2 | 74.6 |
| Arkansas | 48 | 2,395 | 2.0 | 46.0 |
| Louisiana | 88 | 4,408 | 6.2 | 99.0 |
| Mississippi | 52 | 2,620 | 2.5 | 55.5 |
| **South Central:** | 452 | 22,578 | 1.4 | 54.7 |
| Texas | 337 | 16,871 | 1.6 | 64.3 |
| Oklahoma | 65 | 3,242 | 1.3 | 47.2 |
| Kansas | 50 | 2,495 | 0.7 | 30.1 |
| **Southwest:** | 666 | 33,310 | 3.8 | 85.2 |
| California | 566 | 28,314 | 11.6 | 181.2 |
| Arizona | 70 | 3,489 | 1.2 | 30.7 |
| New Mexico | 30 | 1,507 | 0.4 | 12.4 |

[a] Program area totals are weighted averages of State population densities.
[b] Estimated using U.S. average of farm population as percentage of total (2.0%).
[c] Farm population divided by land in farms.

Source: U.S. Census Bureau, 1990, Table 26; USDA, 1990, Tables 535 and 546.

## Special Groups

### American Indian Reservations

Numerous American Indian reservations are located throughout the Cotton Belt, although most are in New Mexico and Arizona. One of the primary commodities grown on the reservations in these States is cotton. In most cases, small cotton fields are planted in areas that are used for both agricultural and nonagricultural purposes (EPA, 1979).

### Potentially Sensitive Individuals

Individuals vary in their susceptibility to toxic substances in the environment. Variations in susceptibility can be the result of diet, age, heredity, preexisting diseases, and lifestyle (Calabrese, 1978). Although the U.S. population has not been statistically characterized for most of

Table 3-3. Total U.S. Resident and Farm Population, 1979-89

| Year | Farm population | | Total population | | Farm population as percentage of total |
|---|---|---|---|---|---|
| | Number (thousands) | Change (percent) | Number (thousands) | Change (percent) | |
| 1979 | 6,241 | — | 224,438 | — | 2.8 |
| 1980 | 6,051 | –3.0 | 227,061 | +1.2 | 2.7 |
| 1981 | 5,850 | –3.3 | 229,542 | +1.1 | 2.5 |
| 1982 | 5,628 | –3.8 | 231,932 | +1.0 | 2.4 |
| 1983 | 5,787 | +2.8 | 234,237 | +1.0 | 2.5 |
| 1984 | 5,754 | –0.6 | 237,001 | +1.2 | 2.4 |
| 1985 | 5,355 | –6.9 | 239,279 | +1.0 | 2.2 |
| 1986 | 5,226 | –2.4 | 241,625 | +1.0 | 2.2 |
| 1987 | 4,986 | –4.6 | 243,934 | +1.0 | 2.0 |
| 1988 | 4,951 | –0.7 | 246,329 | +1.0 | 2.0 |
| 1989 | 4,801 | –3.0 | 248,762 | +1.0 | 1.9 |

Source: USDA, 1990, Table 546.

these factors, the young and the elderly are generally more sensitive than other groups.

In Cotton Belt States, the potentially susceptible young and elderly populations constitute 35 to 42 percent of the total population (table 3-4). However, there is no information on the portion of this young and elderly population that lives in the cotton-producing areas or the portion that is actually affected by susceptibility to toxic substances.

### Background Health Risks in the Cotton Belt

People in the Cotton Belt appear to be exposed to risks from accidents and injuries at the same rate as the U.S. population as a whole. Injuries are the principal cause of death among young adults and children (NRC, 1985). Nationwide, the chance of developing some form of cancer during one's lifetime is about 1 in 4 (Calabrese and Dorsey, 1984; NRC, 1987). Mortality rates for the leading causes of death in the program regions are presented in table 3-5.

## Economics

### Economy of the Cotton Belt

Cotton is an important component of the economies of Cotton Belt States. Production provides employment and personal income at every stage of processing—from raw fiber to textiles, oil, and livestock feed. In approximately one-half of the Cotton Belt States, cotton was one of the two most valuable crops produced in 1988 (table 3-6).

**Table 3-4. Populations of Young and Elderly Persons in Program States, 1988**

| Program | Under age 18 | | Age 65 and older | |
|---|---|---|---|---|
| | Number | Percent | Number | Percent |
| **Southeast:** | | | | |
| Coastal— | | | | |
| Alabama | 1,115,000 | 27 | 513,000 | 13 |
| Florida | 2,795,000 | 23 | 2,201,000 | 18 |
| Georgia | 1,776,000 | 28 | 636,000 | 10 |
| North Carolina | 1,636,000 | 25 | 774,000 | 12 |
| South Carolina | 949,000 | 27 | 379,000 | 11 |
| Virginia | 1,470,000 | 24 | 640,000 | 11 |
| Delta— | | | | |
| Arkansas | 649,000 | 27 | 350,000 | 15 |
| Louisiana | 1,296,000 | 29 | 479,000 | 11 |
| Mississippi | 780,000 | 30 | 321,000 | 12 |
| Missouri | 1,312,000 | 26 | 710,000 | 14 |
| Tennessee | 1,253,000 | 26 | 611,000 | 13 |
| Subtotal | 15,031,000 | 26 | 7,614,000 | 13 |
| **South Central:** | | | | |
| Kansas | 653,000 | 26 | 338,000 | 14 |
| Oklahoma | 882,000 | 27 | 422,000 | 13 |
| Texas | 4,986,000 | 30 | 1,666,000 | 10 |
| Subtotal | 6,521,000 | 29 | 2,426,000 | 11 |
| **Southwest:** | | | | |
| Arizona | 952,000 | 27 | 447,000 | 13 |
| California | 7,494,000 | 27 | 3,011,000 | 11 |
| New Mexico | 449,000 | 30 | 155,000 | 10 |
| Subtotal | 8,895,000 | 27 | 3,613,000 | 11 |
| Total | 30,447,000 | 27 | 13,653,000 | 12 |

Source: U.S. Census Bureau, 1990, Table 28.

In most Cotton Belt States, however, manufacturing, trade, and services provide the largest contribution to State revenue and employment (tables 3-7 and 3-8). Construction, agriculture, fishing, and mining contribute smaller, but still significant, revenue to these States. The following sections discuss the agricultural sector of Cotton Belt States in greater detail and provide a specialized look at the economics of cotton production and the losses attributed to the boll weevil.

## The Agricultural Sector

Commodities produced by the agricultural sector may be classified as livestock or crops. Livestock commodities, the more valuable class of commodities in more than two-thirds of all Cotton Belt States, include cattle, broilers, and dairy products. Leading crop commodities include

**Table 3-5. Mortality Per 100,000 Population and Causes of Death in the Cotton Belt, 1986**

| Program area | Cause of death | | | | |
|---|---|---|---|---|---|
| | All | Cardiovascular and cerebrovascular disease | Cancer | Chronic respiratory disease | Accidents |
| **Southeast:** | 905.2 | 400.0 | 196.0 | 30.8 | 49.0 |
| Coastal | 882.3 | 388.2 | 193.5 | 31.0 | 48.1 |
| Delta | 932.6 | 414.1 | 198.9 | 30.7 | 50.1 |
| **South Central:** | 841.4 | 374.9 | 177.2 | 30.1 | 43.2 |
| **Southwest:** | 738.8 | 285.1 | 163.5 | 36.2 | 48.7 |
| **Total United States** | 873.2 | 389.0 | 194.7 | 31.8 | 39.5 |

Source: U.S. Census Bureau, 1990, Table 118.

soybeans, wheat, corn, cotton, hay, tobacco, tomatoes, and grapes (table 3-6). Sales of crops represented at least half of the total 1987 farm sales in 5 of the 17 Cotton Belt States—ranging from $470 million in South Carolina to $10.8 billion in California. Total crop revenues were $31.4 billion, or 48 percent of the Cotton Belt States' farm receipts (Hornor, 1990).

## The Cotton Industry

The cotton industry can be described in terms of cotton supply, revenues, and use (fig. 3-10).

### Supply

Each year's cotton supply is determined by domestic production, imports, and the amount remaining from the previous year's supply (called carryover).

Production totaled 15.4 million bales in 1988, with the Southeast States contributing nearly 40 percent of the total (table 3-9). The Southwest States (California, Arizona, and New Mexico) produced 26 percent of total production; Texas, Oklahoma, and Kansas in the South Central area produced 36 percent.

Less than 1 percent of the domestic cotton supply is imported. Brazil, Turkey, and Mexico supplied 73 percent of all imported cotton lint in 1988-89 (USDA, 1990).

### Revenues

The value of the cotton lint and cottonseed produced in 1988 was $4.9 billion. Cotton lint, worth $4.2 billion, accounted for 13 percent of the value of all crops that year (table 3-6). The cottonseed produced

**Table 3-6. Value of All Crops and Cotton, 1988**

| Program area | Crop values (millions of dollars) | | Cotton as a percentage of total crop value | Crops in order of value |
|---|---|---|---|---|
| | Total | Cotton | | |
| **Southeast:** | | | | |
| Coastal— | | | | |
| Alabama | 567 | 97.2 | 17 | Peanuts, soybeans, hay, cotton lint |
| Georgia | 1,297 | 98.0 | 8 | Peanuts, soybeans, tobacco |
| South Carolina | 606 | 36.0 | 6 | Tobacco, soybeans, peaches, wheat |
| North Carolina | 1,865 | 34.5 | 2 | Tobacco, soybeans, corn, peanuts |
| Virginia | 733 | 0.9 | <1 | Hay, soybeans, tobacco |
| Florida | 2,728 | 8.5 | <1 | Oranges, peanuts, hay, tobacco |
| Delta— | | | | |
| Tennessee | 956 | 151.1 | 16 | Soybeans, cotton lint, hay, tobacco |
| Missouri | 2,162 | 78.6 | 4 | Soybeans, hay, corn, wheat |
| Arkansas | 1,728 | 272.6 | 16 | Soybeans, rice, cotton lint, wheat |
| Louisiana | 995 | 248.0 | 25 | Soybeans, cotton lint, rice, hay |
| Mississippi | 1,190 | 470.4 | 40 | Cotton lint, soybeans, rice, wheat |
| Subtotal | 14,827 | 1,495.8 | 10 | |
| **South Central:** | | | | |
| Texas | 3,554 | 1,329.3 | 37 | Cotton lint, hay, corn, sorghum |
| Oklahoma | 1,184 | 68.1 | 6 | Wheat, hay, peanuts, cotton lint |
| Kansas | 2,850 | 0.2 | <1 | Wheat, sorghum, hay, corn |
| Subtotal | 7,588 | 1,397.6 | 18 | |
| **Southwest:** | | | | |
| California | 8,492 | 878.8 | 10 | Grapes, cotton lint, hay, tomatoes |
| Arizona | 1,075 | 374.0 | 35 | Lettuce, cotton lint, cottonseed, hay |
| New Mexico | 327 | 44.3 | 14 | Hay, onions, cotton lint, corn |
| Subtotal | 9,894 | 1,297.1 | 13 | |
| Total | 32,309 | 4,190.5 | 13 | |

Sources: U.S. Census Bureau, 1990, Table 1149; USDA, 1990, Table 84.

**Table 3-7. Value of Goods and Services Produced in the Cotton Belt, 1986 (percent of total)**

| Program area | Farms | Agriculture services, forestry, and fisheries | Mining | Construction | Manufacturing | Transportation and public utilities | Wholesale | Retail | Finance, real estate, and insurance | Service | Other | Total (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Southeast:** | 2 | 0.4 | 2 | 5 | 20 | 10 | 7 | 10 | 15 | 15 | 13 | $879,322 |
| Coastal— | 2 | 0.4 | 1 | 5 | 20 | 9 | 7 | 11 | 15 | 15 | 14 | 585,571 |
| Alabama | 2 | 0.4 | 3 | 3 | 23 | 10 | 7 | 10 | 13 | 13 | 16 | 55,007 |
| Georgia | 2 | 0.3 | 1 | 5 | 21 | 11 | 10 | 10 | 14 | 14 | 13 | 102,992 |
| South Carolina | 1 | 0.4 | 0 | 4 | 27 | 8 | 6 | 11 | 13 | 12 | 17 | 44,727 |
| North Carolina | 2 | 0.4 | 0 | 4 | 31 | 9 | 6 | 10 | 13 | 12 | 12 | 100,961 |
| Virginia | 1 | 0.3 | 1 | 6 | 18 | 9 | 5 | 9 | 15 | 16 | 19 | 104,155 |
| Florida | 2 | 0.7 | 1 | 7 | 11 | 9 | 7 | 12 | 19 | 19 | 12 | 177,729 |
| Delta— | 2 | 0.3 | 5 | 5 | 21 | 10 | 6 | 10 | 15 | 14 | 11 | 293,751 |
| Tennessee | 2 | 0.3 | 0 | 4 | 25 | 8 | 7 | 11 | 14 | 15 | 12 | 72,328 |
| Missouri | 2 | 0.3 | 0 | 4 | 23 | 11 | 7 | 10 | 16 | 16 | 10 | 83,534 |
| Arkansas | 6 | 0.4 | 2 | 5 | 25 | 10 | 5 | 10 | 14 | 12 | 10 | 31,633 |
| Louisiana | 1 | 0.3 | 17 | 5 | 13 | 11 | 6 | 9 | 15 | 13 | 10 | 74,426 |
| Mississippi | 3 | 0.4 | 3 | 4 | 27 | 9 | 5 | 11 | 13 | 11 | 13 | 31,830 |
| **South Central:** | 2 | 0.3 | 9 | 5 | 16 | 11 | 7 | 9 | 14 | 14 | 11 | 395,796 |
| Texas | 2 | 0.3 | 10 | 5 | 16 | 11 | 8 | 9 | 14 | 14 | 11 | 303,510 |
| Oklahoma | 3 | 0.3 | 10 | 4 | 14 | 11 | 6 | 10 | 14 | 13 | 14 | 49,814 |
| Kansas | 7 | 0.3 | 2 | 4 | 19 | 12 | 7 | 9 | 15 | 13 | 12 | 42,472 |
| **Southwest:** | 2 | 0.6 | 2 | 5 | 18 | 8 | 7 | 10 | 17 | 19 | 12 | 609,672 |
| California | 1 | 0.6 | 1 | 4 | 18 | 8 | 7 | 10 | 18 | 19 | 12 | 533,816 |
| Arizona | 2 | 0.6 | 1 | 10 | 14 | 9 | 5 | 12 | 17 | 17 | 12 | 52,253 |
| New Mexico | 2 | 0.3 | 13 | 7 | 8 | 10 | 4 | 9 | 14 | 15 | 17 | 23,603 |
| Total Cotton Belt | 2 | 0.5 | 4 | 5 | 19 | 9 | 7 | 10 | 16 | 16 | 12 | 1,884,790 |
| United States | 2 | 0.4 | 2 | 5 | 20 | 9 | 7 | 10 | 17 | 17 | 12 | 4,191,705 |

Source: Hornor, 1990.

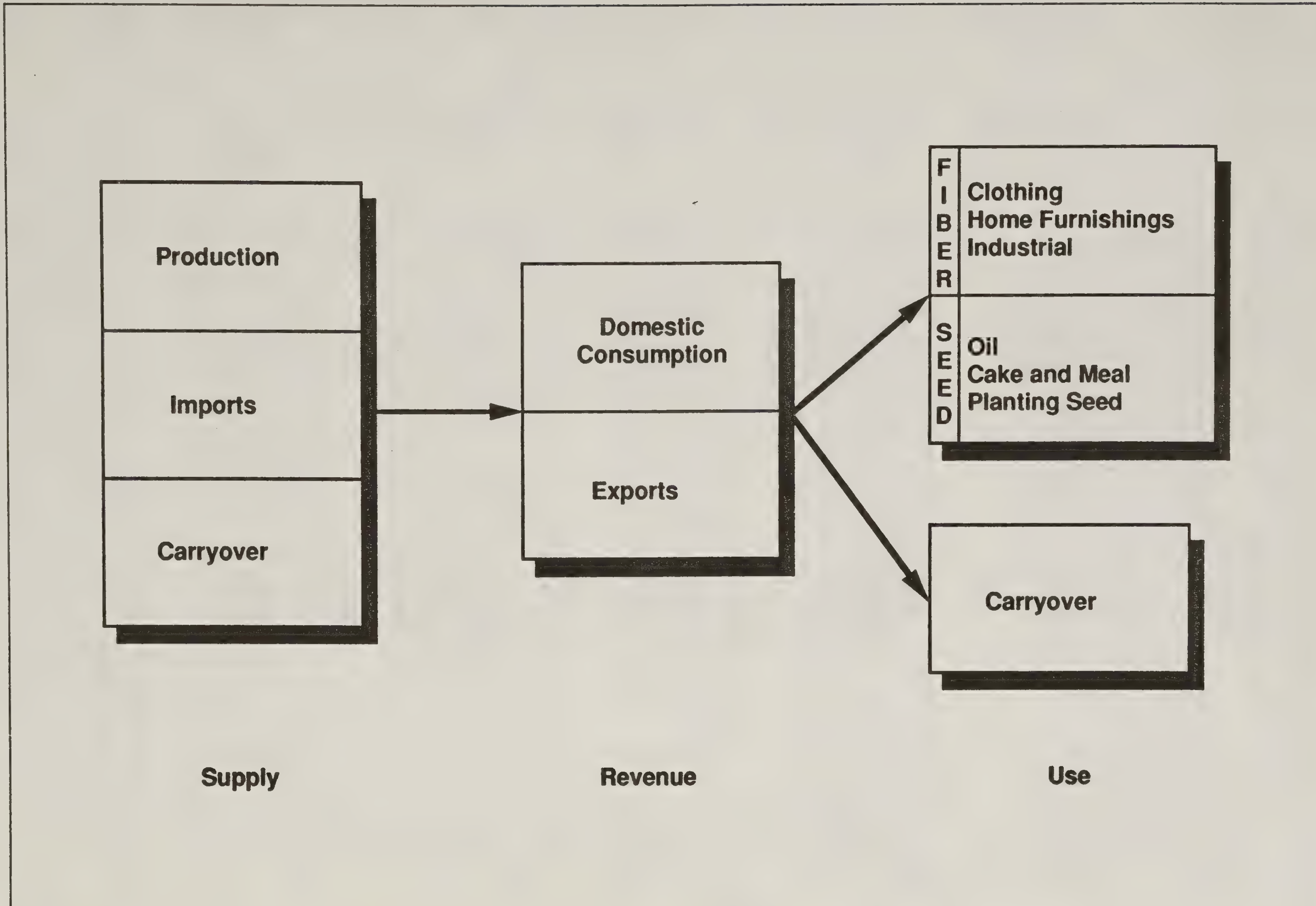
**Table 3-8. Industry Payroll in the Cotton Belt, 1987 (percent of total)**

| Program area | Agriculture | Mining | Construction | Manufacturing | Transportation | Wholesale | Retail | Finance, real estate, and insurance | Service | Non-classifiable | Total (millions) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Southeast:** | 0.4 | 1 | 7 | 28 | 9 | 8 | 13 | 8 | 23 | 0.4 | 388,173 |
| Coastal— | 0.5 | 1 | 8 | 27 | 9 | 8 | 14 | 9 | 24 | 0.3 | 235,191 |
| Alabama* | 0.3 | 2 | 8 | 34 | 9 | 8 | 12 | 7 | 19 | 1 | 19,306 |
| Georgia | 0.4 | 0.5 | 7 | 28 | 11 | 10 | 13 | 9 | 21 | 0.2 | 43,554 |
| South Carolina | 0.5 | 0.2 | 10 | 40 | 6 | 6 | 14 | 6 | 18 | 0.2 | 18,713 |
| North Carolina | 0.4 | 0.2 | 6 | 40 | 9 | 8 | 12 | 6 | 18 | 0.2 | 41,498 |
| Virginia | 0.4 | 1 | 8 | 24 | 9 | 7 | 13 | 8 | 28 | 0.2 | 39,831 |
| Florida | 0.7 | 0.5 | 8 | 16 | 8 | 8 | 16 | 12 | 31 | 0.5 | 72,289 |
| Delta— | 0.3 | 2 | 7 | 31 | 9 | 8 | 13 | 8 | 22 | 1 | 102,982 |
| Tennessee* | 0.2 | 1 | 6 | 35 | 7 | 9 | 12 | 7 | 22 | 1 | 27,381 |
| Missouri* | 0.3 | 1 | 7 | 30 | 10 | 9 | 12 | 8 | 22 | 1 | 33,831 |
| Arkansas | 0.5 | 1 | 5 | 37 | 10 | 7 | 14 | 7 | 19 | 0.2 | 10,655 |
| Louisiana | 0.3 | 9 | 8 | 20 | 10 | 8 | 14 | 8 | 24 | 0.3 | 21,543 |
| Mississippi* | 0.4 | 2 | 5 | 38 | 8 | 7 | 14 | 8 | 16 | 1 | 9,572 |
| **South Central:** | 0.3 | 5 | 7 | 24 | 9 | 9 | 13 | 9 | 23 | 0.4 | 137,002 |
| Texas | 0.4 | 5 | 7 | 23 | 9 | 9 | 13 | 10 | 24 | 0.4 | 107,160 |
| Oklahoma | 0.3 | 9 | 5 | 24 | 10 | 8 | 13 | 8 | 22 | 0.3 | 15,900 |
| Kansas* | 0.3 | 2 | 6 | 32 | 9 | 9 | 13 | 8 | 20 | 1 | 13,942 |
| **Southwest:** | 0.5 | 1 | 7 | 25 | 8 | 9 | 12 | 10 | 28 | 0.3 | 253,263 |
| California | 0.5 | 1 | 7 | 26 | 8 | 9 | 12 | 10 | 28 | 0.3 | 225,507 |
| Arizona | 0.6 | 2 | 9 | 22 | 7 | 7 | 14 | 11 | 26 | 0.3 | 21,155 |
| New Mexico | 0.3 | 7 | 8 | 11 | 10 | 6 | 15 | 8 | 34 | 0.3 | 6,601 |
| Total Cotton Belt | 0.4 | 2 | 7 | 26 | 9 | 9 | 13 | 9 | 25 | 0.4 | 728,438 |
| United States | 0.4 | 2 | 6 | 29 | 8 | 9 | 12 | 9 | 24 | 1 | 1,608,811 |

* 1986 payroll; 1987 data not available.

Source: Hornor, 1990.

Figure 3-10. Cotton Supply, Revenues, and Use




Source: USDA 1987.

## Table 3-9. Cotton Production by State, 1988

| Program area | Production (1,000 bales)[a] | Value of production (thousands of dollars) | Yield per harvested acre | |
|---|---|---|---|---|
| | | | Pounds | Bales |
| **Southeast:** | | | | |
| Coastal— | | | | |
| Alabama | 380.0 | 97,219 | 486 | 1.0 |
| Georgia | 370.0 | 98,035 | 564 | 1.2 |
| South Carolina | 140.0 | 36,019 | 473 | 1.0 |
| North Carolina | 133.0 | 34,474 | 515 | 1.1 |
| Virginia | 3.4 | 881 | 510 | 1.1 |
| Florida | 34.2 | 8,536 | 566 | 1.2 |
| Delta— | | | | |
| Tennessee | 584.0 | 151,092 | 529 | 1.1 |
| Missouri | 306.0 | 78,581 | 607 | 1.3 |
| Arkansas | 1,044.0 | 272,609 | 742 | 1.5 |
| Louisiana | 948.0 | 247,997 | 705 | 1.5 |
| Mississippi | 1,825.0 | 470,412 | 736 | 1.5 |
| Subtotal | 5,767.6 | 1,495,855 | 648 | 1.4 |
| **South Central:** | | | | |
| Texas | 5,281.5 | 1,329,317 | 475 | 1.0 |
| Upland | 5,215.0 | 1,291,651 | 472 | 1.0 |
| Pima | 66.5 | 37,666 | 769 | 1.6 |
| Oklahoma | 303.0 | 68,066 | 334 | 0.7 |
| Kansas | 0.7 | 157 | 373 | 0.8 |
| Subtotal | 5,585.2 | 1,397,540 | 464 | 1.0 |
| **Southwest:** | | | | |
| California | 2,827.2 | 878,833 | 1,015 | 2.1 |
| Upland | 2,824.0 | 877,021 | 1,015 | 2.1 |
| Pima | 3.2 | 1,812 | 853 | 1.8 |
| Arizona | 1,106.0 | 373,996 | 1,113 | 2.3 |
| Upland | 865.0 | 237,494 | 1,190 | 2.5 |
| Pima | 241.0 | 136,502 | 904 | 1.9 |
| New Mexico | 125.5 | 44,264 | 694 | 1.4 |
| Upland | 102.0 | 30,502 | 710 | 1.5 |
| Pima | 23.5 | 13,762 | 634 | 1.3 |
| Subtotal | 4,058.7 | 1,297,093 | 1,025 | 2.1 |
| Total | 15,411.5 | 4,190,488 | 619 | 1.3 |

[a] 480-pound net weight bales.

Note: Figures are for upland cotton, unless noted otherwise.

Source: USDA, 1990b, Tables 82 and 84.

was valued at $718 million (USDA, 1990). In 1988, cotton was among the most valuable crops in all of the States in the Southwest program area, and in one-half of those in the Southeast and South Central areas.

Cotton represented 3 percent of the total value of U.S. exports in 1986 (DOC, 1988). The United States is the largest exporter of cotton, providing 5 percent of foreign cotton supply in 1988-89 (USDA, 1990). Pakistan, the Soviet Union, China, Australia, and the United States contributed approximately two-thirds of the cotton traded in international markets. Japan and Korea received more than 40 percent of the U.S. cotton exports in 1988-89, with the remainder exported to more than 30 other countries (USDA, 1990).

### Use

Growers send their harvested cotton to cotton gins, where cotton fiber and cottonseed are separated. Specialized cotton gins remove the short fibers (linters) that adhere to the seed after the first ginning process. The ginned fiber is sold to textile mills and is used to produce fabric for clothing, home furnishings, and industrial goods. Cotton linters are used in the production of plastics and numerous other products, such as cotton felt.

Cottonseeds are sold to growers for planting the following season and to oilseed mills. The mills crush the seeds for processing into oil and cottonseed cake and meal. Cottonseed oil is used in margarines and shortening; cake and meal is purchased by farmers for livestock feed. Cottonseed hulls, the remnants of the oil processing, are sold for dairy feed.

### Boll Weevil Damage to Cotton

Climate, soil, and crop damage from insects influence cotton yield. Historically, most losses in cotton yield have been attributed to weather-related causes, including drought, floods, windstorms, and hail. Between 1981 and 1984, an estimated 7.4 percent of the U.S. cotton crop was destroyed by insects and mites, 1.5 percent of this by boll weevils (Suguiyama and Osteen, 1988). Yield losses attributed to the boll weevil ranged from 0.67 percent of the cotton crop in Arizona to 6.62 percent in Florida (table 3-10).

Boll weevil infestations during the 1987 growing season resulted in even greater losses than those that occurred in the early 1980s. It is estimated that more than 300,000 bales of cotton were lost in 1987 because of boll weevils (King et al., 1988). The value of the cotton destroyed by boll weevils totaled $56.7 million. States in the Delta subarea lost more than $24 million, 43 percent of the total value lost.

## Cultural Resources

Many cultural resources are located near cotton fields, including historic sites associated with agricultural development. The rich history of cotton production is preserved, in part, by the restoration and designation of 18th and 19th century historic buildings and plantations. Attractive scenery and natural resources designated for environmental protection, such as lands within the National Park System, are also

**Table 3-10. Cotton Yield, Value, and Loss Caused by the Boll Weevil, 1984**

| Program area | Production (1,000 bales)[a] | Value of production (thousands of dollars) | Yield loss (percent) | Value of loss (thousands of dollars) | Production loss (1,000 bales) |
|---|---|---|---|---|---|
| **Southeast:** | | | | | |
| Coastal— | | | | | |
| Alabama | 447.0 | 118,652 | 5.13 | 6,086.8 | 22.9 |
| Georgia | 281.0 | 78,770 | 3.74 | 2,946.0 | 10.5 |
| South Carolina | 170.0 | 49,776 | 4.30 | 2,140.4 | 7.3 |
| North Carolina | 120.0 | 35,597 | 1.83 | 651.4 | 2.2 |
| Virginia | 1.1 | 333 | — | — | — |
| Florida | 30.0 | 8,338 | 6.62 | 552.0 | 2.0 |
| Delta— | | | | | |
| Tennessee | 337.0 | 90,909 | 0.82 | 745.4 | 2.8 |
| Missouri | 187.0 | 51,971 | — | — | — |
| Arkansas | 612.0 | 163,331 | 1.94 | 3,168.6 | 11.9 |
| Louisiana | 1,056.0 | 275,236 | 3.65 | 10,046.1 | 38.5 |
| Mississippi | 1,650.0 | 429,264 | 2.39 | 10,259.4 | 39.4 |
| Subtotal | 4,891.1 | 1,302,177 | 2.7 | 36,596.1 | 137.5 |
| **South Central:** | | | | | |
| Texas | 3,709.9 | 940,234 | 1.78 | 16,736.2 | 66.0 |
| Upland | 3,680.0 | 927,360 | | | |
| Pima | 29.9 | 12,874 | | | |
| Oklahoma | 183.0 | 42,427 | 1.51 | 1,018.1 | 2.8 |
| Kansas | 0.3 | 70 | — | — | — |
| Subtotal | 3,893.2 | 982,731 | 1.6 | 17,754.3 | 68.8 |
| **Southwest:** | | | | | |
| California | 2,913.0 | 934,024 | N.A. | N.A. | N.A. |
| Arizona | 1,185.1 | 353,661 | 0.67 | 2,369.5 | 7.9 |
| Upland | 1,097.0 | 314,883 | | | |
| Pima | 88.1 | 38,778 | | | |
| New Mexico | 99.4 | 30,841 | N.A. | N.A. | N.A. |
| Upland | 87.0 | 24,972 | | | |
| Pima | 12.4 | 5,869 | | | |

**Table 3-10. Cotton Yield, Value, and Loss Caused by the Boll Weevil, 1984 (continued)**

| Program area | Production (1,000 bales)[a] | Value of production (thousands of dollars) | Yield loss (percent) | Value of loss (thousands of dollars) | Production loss (1,000 bales) |
|---|---|---|---|---|---|
| Subtotal | 4,197.5 | 1,318,526 | 0.67 | 2,369.5 | 7.9 |
| Total | 12,981.8 | 3,603,434 | 1.5 | 56,719.9 | 214.2 |

[a] 480-pound net weight bales.

Notes: Figures are for upland cotton unless noted otherwise. — indicates unreported or insignificant estimate. N.A. indicates not available.

Source: USDA, 1988b, Tables 82 and 84; Suguiyana and Osteen, 1988.

considered to be cultural resources and may be found near areas where cotton is grown.

**Southeast Program Area**

The Southeast program area has a rich, historic association with cotton. Plantations for growing cotton have existed for more than a century and are considered to be among the area's cultural treasures. A number of antebellum mansions with ornate furnishings are listed in the National Register of Historic Places, a basic inventory of the historical and archaeological resources of the United States. Other properties are currently under consideration for inclusion in the National Register. The Historic Preservation Officer for each State maintains a list of the properties that are significant at the local or State level.

National Park System lands, especially Civil War battlefield parks, are found near cotton-producing areas in this program area (USDI, 1985). These areas also have national significance; many have received special recognition through various acts of Congress.

A unique cultural landmark, a monument to the boll weevil, is located in Enterprise, Alabama. The monument was erected by the town because local farmers prospered from peanut crops planted as a substitute for frequently infested cotton fields (Ebeling, 1979).

**South Central Program Area**

In the South Central program area, cotton did not play as pivotal a role in regional development as it did in the Southeastern United States. However, cotton was one of several crops planted by early settlers, and it has remained well integrated in the region's cultural and economic development.

This program area contains a wealth of National Park System lands and historical sites from the early era of Texas statehood. Battles with Mexico were common along the present border between the United States and Mexico. Early religious structures, including buildings within the San Antonio Missions National Historical Park, are also located near cotton fields.

**Southwest Program Area**

Lack of water caused a slow introduction of cotton planting in the Southwest program area. However, as soon as irrigation began, settlers began planting cotton as part of their crop mix, and today cotton is among the top three crops produced in the region.

Evidence of early American Indian cultures, though more plentiful north of the cotton region, is found in this program area. Cotton is a major crop for many Indian Reservations in this program area. Homes and evidence of past habitation can occasionally be found around cotton fields. Indian lands and sacred places are also important cultural resources. The Casa Grande Monument, located adjacent to the Gila River Indian Reservation, and Hohokam Pima National Monument, located within the Gila River Indian Reservation, are two examples of federally protected Indian sites (USDI, 1985). Cotton is the prime cash crop for this Reservation, as it is for most Indian Reservations in Arizona. The Sequoia National Park lies about 15 miles to the east of

the cotton fields in the San Joaquin Valley of California. Some cultural resources in this region may be within or adjacent to the area of cotton production.

## Visual Resources

Throughout the Cotton Belt, cotton fields are part of the agricultural landscape. Cotton fields are usually planted on level ground and are not visually stimulating in the sense of topography or geology. However, cotton fields create a colorful expanse of land that accents more distant land features and adds to the general feeling of spaciousness attributed to agricultural areas.

### Southeast Program Area

The geology, physiography, and vegetative cover of the Southeast program area are similar in the Coastal and Delta program subareas. Although most of the area is fairly flat to rolling, the varied nature of the vegetation creates a pleasing visual environment. Willow trees, hardwood stands, and stretches of loblolly pine can be found in different parts of the Southeast. Meandering rivers in the Delta subarea help provide a soothing environment. Expansive views of the Central Plains can be seen from the rolling Piedmont and the steeper terrain of the Appalachian Mountains.

### South Central Program Area

The Texas landscape can change dramatically over short distances, north and south, as well as east and west. Mountains, coastal plains, high plains, and rolling terrain provide a varied and scenic environment. However, the expanse of the Rolling Plains is unbroken by any unique landforms and is not a stimulating environment. The effect of the Guadalupe Mountains jutting up from the High Plains creates a breathtaking view.

### Southwest Program Area

The desertlike environment of the Southwest is a favorite subject for artists. The sands are derived from a variety of colored rock formations, providing colorful scenery. Sunrises and sunsets particularly enhance the natural hues to create fascinating panoramas of color on the rocks. Steep mountain peaks rise just north of the cotton fields of this region. Saguaro cactus and other cactus varieties dot southern Arizona. Massive sandstone structures sculpted by wind and water are common in the Southwest program area and are visible for many miles. This program area also includes some national forests.

## Air Quality

The Clean Air Act, as amended, divides the United States into Federal Air Quality Control Regions (AQCRs) on the basis of pollutant concentrations, geography, and economics. The Cotton Belt is located in portions of four of these regions.

Individual States are required to ensure that concentrations of designated pollutants do not exceed air quality standards for more than allowable periods. Air quality is measured by comparing air pollutant levels with appropriate primary and secondary National Ambient Air Quality Standards for each of six "criteria" air pollutants: total-suspended particulates, sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead. Primary standards protect public health and

secondary standards protect the public welfare, as measured by effects of pollution on vegetation, materials, and visibility.

In most areas of the Cotton Belt, the National Ambient Air Quality Standards have been achieved for sulfur dioxide, total-suspended particulates, nitrogen dioxide, and lead. Carbon monoxide is still a problem in southern California, Texas, and the Gulf States. Ozone is also a problem in most urban areas of the South and Southwest (CEQ, 1984).

Air quality in rural areas of the Cotton Belt is generally good. However, air-monitoring data from suburban locations in three Cotton Belt cities (Montgomery, Alabama; Little Rock, Arkansas; and Monroe, Louisiana) have shown significantly higher airborne residues from cotton insecticides than are found in cities monitored outside the Cotton Belt (NRC, 1981). This trend was first documented in the early 1970s in Mississippi and Alabama (Stanley et al., 1971; Arthur et al., 1976). In addition, limited and isolated particulate emissions occur in the Cotton Belt as a result of harvesting and ginning operations (EPA, 1985).

## Noise

The sound environment may be characterized by ambient noise level and factors that influence that noise level. In general, rural and agricultural areas have a much lower average background noise level than more industrialized areas. Annual noise levels in rural communities have been estimated by EPA at 35 to 40 decibels (EPA, 1974; 1982). However, periodic increases in decibel levels may occur from the operation of agricultural equipment, such as tractors, harvesters, and aircraft, used to apply pesticides.

The sound environment also may be described in terms of the number and type of sensitive receptors. The receptors include hospitals, residences, and noise-sensitive wildlife habitats. The number and sensitivity of these receptors vary, depending on the locale.

# Chapter 4

# Environmental Consequences

## Introduction

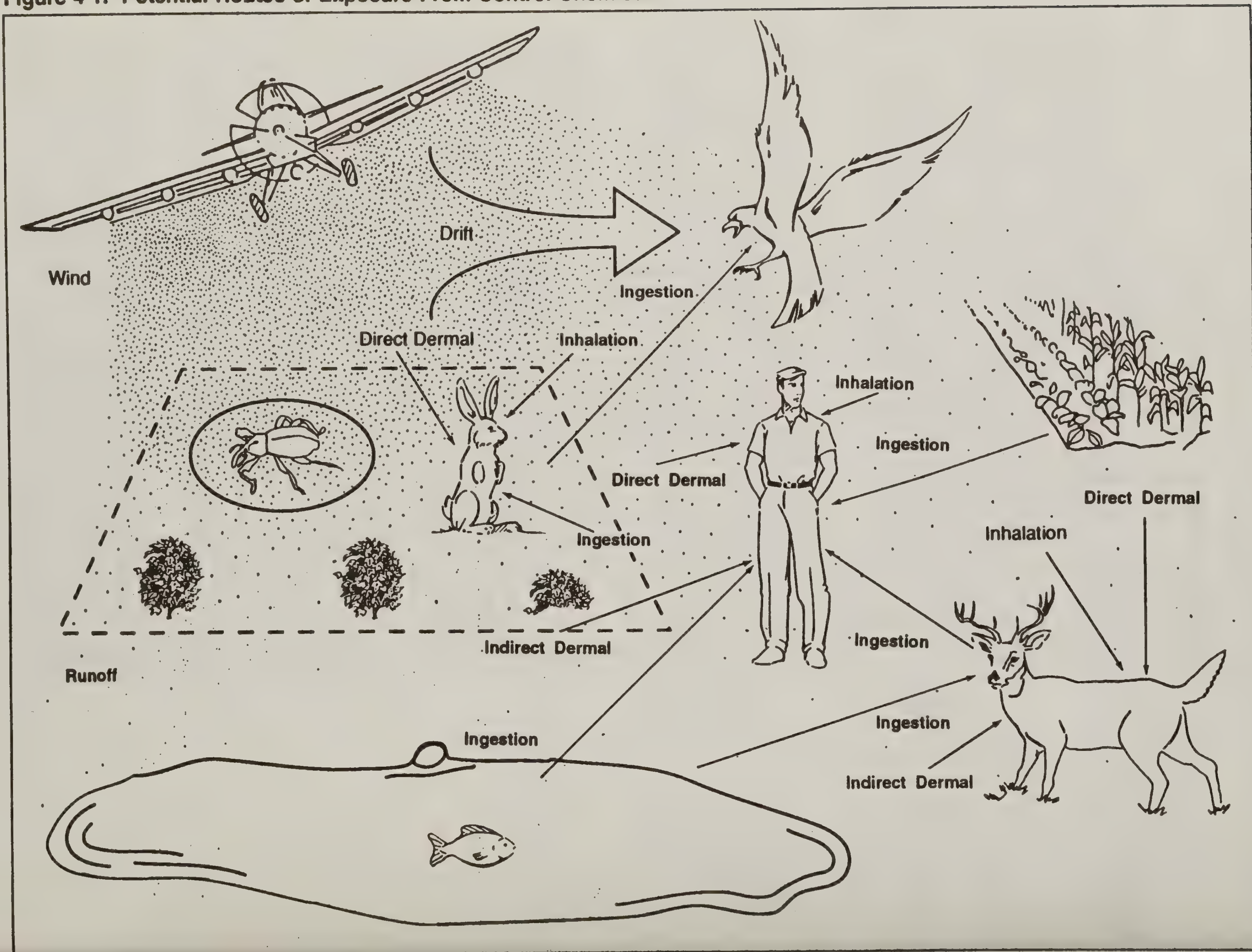
This chapter discusses the potential impacts of program alternatives and boll weevil control methods on the environment of the Cotton Belt of the United States. Each control method and program alternative was analyzed to determine its effects on the following resource elements: soils; vegetation; water quality; nontarget wildlife, aquatic, and insect species; public health and occupational safety; air quality; noise levels; visual resources; and costs of control methods and program alternatives. This chapter also presents a discussion of cumulative and synergistic environmental effects, unavoidable environmental effects, irreversible and irretrievable commitment of resources, short-term uses versus long-term productivity, conflicts with other agencies, and energy requirements.

The impacts of boll weevil control activities on endangered and threatened species are discussed in detail in a biological assessment prepared by the Animal and Plant Health Inspection Service (APHIS) for the 17 Cotton Belt States. A summary biological assessment can be found in appendix H. In accordance with 40 CFR 1502.20, the findings of the biological assessment are incorporated by reference into this final environmental impact statement (EIS) for the National Boll Weevil Cooperative Control Program.

A risk assessment involving three steps—hazard analysis, exposure analysis, and risk analysis—was conducted to determine the effects of the chemical control method on human health, wildlife, and aquatic organisms. Appendix B describes in detail the hazards of malathion, azinphos-methyl, diflubenzuron, methyl parathion, chlorpyrifos, and propoxur to humans, wildlife, and aquatic species. Appendix B also describes in detail the toxicity of xylene, an inert ingredient found in the microencapsulated formulation of methyl parathion proposed for use in the program. In addition, appendix B presents a review of the environmental fate properties of xylene and the four insecticides proposed for foliar application and the details of the exposure and risk analyses calculations for humans, wildlife, and aquatic organisms. The environmental fate properties of chlorpyrifos and propoxur were not analyzed because these chemicals would be used only in enclosed traps; they are not expected to disseminate in the environment. The risk analyses for humans, wildlife, and aquatic organisms are summarized in the discussion of each of these resource elements in this chapter.

The impacts on each resource element are discussed separately. However, the interrelatedness of these environmental components or resource elements, as illustrated by the potential routes of exposure from control chemicals shown in figure 4-1, must be considered in assessing the overall potential impacts of the program. For example, much of the discussion under the first resource element, soils, is also

Figure 4-1. Potential Routes of Exposure From Control Chemicals



pertinent to impacts on vegetation; water quality; nontarget wildlife, aquatic, and insect species; and human health.

The impacts under each resource element are assessed in terms of impacts associated with a particular type of control method (nonchemical or chemical) and impacts under the three major classes of program alternatives (no action or current grower control, beltwide eradication, and beltwide suppression). For analytical purposes in this EIS, the environmental impacts associated with the full and limited Federal involvement alternative options under eradication and suppression were not analyzed separately, although potential differences in impacts are described. The economic impact and public costs associated with these options are analyzed separately.

To ensure that no risks associated with the use of chemical controls are underestimated, this EIS examines the effects of the use of the proposed insecticides under anticipated or typical operational conditions—as well as the effects under unlikely, but theoretically possible, extreme conditions. In addition, the effects of unlikely, but possible, accidents, such as spills on workers, accidental spraying of residences and gardens, and a jettison of insecticide into a reservoir, also are considered. Conservative assumptions are used throughout these analyses in an attempt to avoid overlooking any potential effects, no matter how unlikely their occurrence.

To establish a baseline for the impact analyses of all resource elements, it is assumed that current grower control activities would continue under the no action alternative. Because the National Boll Weevil Cooperative Control Program would not be implemented simultaneously in all areas of the Cotton Belt, interim grower-applied treatments would still be necessary in many areas before program implementation. The long-term effects of these interim grower-applied chemical treatments for boll weevil control must be considered in evaluating cancer risk and economic burden for populations and growers in Cotton Belt States who would not receive immediate benefits from the program.

Throughout this chapter, specific operational and mitigation procedures are described in conjunction with impacts they are designed to mitigate. Operating procedures required by Federal law, as well as operational procedures required to mitigate adverse impacts, are listed in tables 2-1 and 2-2 in chapter 2.

## Scientific Uncertainties

The Council on Environmental Quality recently amended its regulation (40 CFR 1502.22) that addresses incomplete or unavailable information in an EIS. The new regulation provides that in cases where relevant information concerning adverse impacts is not known, the overall costs of obtaining such information are exorbitant, or the means to obtain such information are not known, the agency must include the following in its EIS: a statement identifying the unavailable or incomplete information, a statement explaining the reason why this information is important in the evaluation of impacts, a summary of the existing

credible scientific evidence that is relevant in evaluating the impacts, and the agency's evaluation of these impacts based on a theoretical approach generally accepted by the scientific community.

Information pertaining to the quantitative risk estimation of human health effects, including systemic, reproductive, and carcinogenic risks, is incomplete. Some of these data gaps are studies required by the Environmental Protection Agency (EPA) that have not yet been received or reviewed. Other inherent uncertainties can be found in extrapolating from animal studies to humans and in extrapolating from experimental doses to the doses anticipated in the National Boll Weevil Cooperative Control Program. Human populations are also variable with respect to genetic constitution, diet, occupational and home environment, and numerous cultural factors.

Uncertainties also exist in the quantitative risk estimation of effects on nontarget species because of the limited data on actual doses received as a result of chemical concentrations in the environment. Toxicity and exposure information is available only on a limited number of species, and uncertainty exists when extrapolating the existing data from one species to another because animal species differ in uptake, metabolism, and sensitivity or susceptibility to control measures. Information is often completely lacking for an entire phylum, such as Reptilia.

EPA has reviewed available data supporting the registration of insecticides proposed for use in the National Boll Weevil Cooperative Control Program. Based on that review, EPA has identified data necessary to resolve questions concerning the chemical, toxicological, and environmental characteristics and fate of the insecticides. Some of this information has not yet been formally reviewed by EPA.

The following discussion presents brief summaries of the data gaps that exist for each insecticide proposed for foliar application. This information is not readily available in existing scientific literature.

### Malathion

Of the toxicology studies required for registration of malathion by EPA (1988a), the following studies have not yet been reported as received and reviewed by EPA: an acute delayed neurotoxicity test in hens; a 21-day dermal irritation test in rabbits; a 90-day inhalation study on rats; chronic toxicity studies in rodent and nonrodent species; rat and mouse oncogenicity studies; rat teratogenicity and 2-generation reproduction studies; tests for gene mutation, structural chromosomal changes, and other genotoxic effects; oncogenicity studies on malaoxon (metabolite); and domestic animal safety testing.

Field studies assessing the risks to both aquatic and terrestrial fauna are not adequately documented. Required studies on ecological effects include acute toxicity to freshwater invertebrates, avian reproduction, and residual toxicity to bees.

**Azinphos-methyl**

According to the summary of studies received in support of reregistration of azinphos-methyl (EPA, 1988b) and the reference dose tracking report (EPA, 1988c), the following have not yet been reported as received and reviewed by EPA: a delayed neurotoxicity study in hens, a chronic toxicity study in a rodent, a rat oncogenicity study, and a rabbit teratogenicity study.

Field studies assessing the risks to both terrestrial and aquatic fauna are not adequately documented. Required studies on ecological effects include acute avian oral toxicity testing, avian reproduction studies, acute mammalian toxicity studies, additional aquatic acute and chronic toxicity studies, and testing of residual toxicity to bees.

**Diflubenzuron**

According to EPA (1988c), there are no data gaps for diflubenzuron.

**Methyl Parathion**

EPA (1986a) listed the studies required for reregistration of methyl parathion. According to the summary of studies received in support of reregistration of methyl parathion (EPA, 1988g) and the reference dose tracking report (EPA, 1988d), the following have not yet been reported as received and reviewed by EPA: acute delayed neurotoxicity, 90-day neurotoxicity, special subchronic testing in rats, rodent and nonrodent chronic toxicity tests, rat and mouse oncogenicity tests, rat and rabbit teratogenicity tests, and aquatic field tests on risk to fish and aquatic invertebrates.

Most, if not all, of the research needed to fill the data gaps for the chemicals proposed for use in the National Boll Weevil Cooperative Control Program is currently being conducted by manufacturers as part of the reregistration process for these chemicals as required under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA, Sec. 3(g)). The registration standards program involves a thorough review of the scientific data base underlying pesticide registrations and identification of essential but missing studies that may not have been required when the product was initially registered or studies that are now considered insufficient. EPA has the authority under FIFRA, Section 3(c)(2)(B), to require registrants to submit data that will answer questions regarding the hazard that may result from the use of the pesticide. It would be a duplication of efforts for APHIS to conduct its own research into carcinogenic potential and human exposure, and the overall cost of obtaining such information would be exorbitant.

The time needed to fill the toxicology data gaps ranges from 1 year or less for acute and subchronic studies to 3 years for oncogenicity studies. Estimated costs to conduct such studies range from $114,000 for mutagenicity tests to $484,000 for oncogenicity studies. Information also is lacking on human epidemiology and exposure. Epidemiology studies cost approximately $400,000 per health effect analyzed (for example, effects on the developing fetus or soft-tissue sarcomas). The time needed to complete each health effect study varies considerably, but

often several years are required. The cost of exposure studies ranges from about $10,000 for water residue studies to $300,000 for worker exposure studies. Water residue studies require about 6 months to complete; worker exposure studies require 1 to 3 years. Although APHIS regularly conducts limited worker monitoring (for cholinesterase inhibition), it would be impossible to conduct human exposure studies to cover all site-specific exposure situations involving workers and members of the public. Thus, some extrapolation from existing data bases is required to evaluate risks.

Appendix B of this EIS summarizes the existing information on the proposed chemicals and potential impacts on human health and nontarget species. This EIS has undertaken a risk assessment, a technique generally accepted by the scientific community for analyzing impacts on human health and nontarget species. As mentioned previously, this EIS analyzes a number of extreme, but nevertheless possible, exposure scenarios. These extreme scenarios were developed by modifying routine operating procedures to reflect a substantial increase in insecticide treatments; an increase in the frequency of insecticide treatments; direct insecticide spraying of residences, food crops, and surface water; and numerous worker accidents. It should be emphasized that these extreme scenarios are unlikely events that have been analyzed only to prevent an underestimation of risk.

In addition to the uncertainties inherent in the estimation of risk, a number of program uncertainties exist that must be considered in assessing the potential impacts of a nationwide boll weevil control program. As discussed in chapter 2, an eradication program is expected to result in a long-term reduction in the amount of insecticides applied to cotton fields in the United States. This projection is based on previous eradication trials in North Carolina and past experience with the Southeast Boll Weevil Eradication Program in Virginia, North Carolina, and South Carolina. In these areas, the eradication program required 2½ years of active control treatments and an additional 1½ years of treatment of localized "hot spots." The amount of insecticide used and the number of fields requiring treatment were significantly reduced in each successive year of the program. In addition, growers in these areas currently apply substantially less pesticide to control secondary cotton pests than was required before implementation of the program. This reduced need for treatment may be attributed to better pest management practices that are possible only in the absence of boll weevil treatments.

Similar success is anticipated in other areas of the Cotton Belt, although regional differences may affect the duration of other program increments and the total number of required insecticide treatments. Factors that may influence this variability include the degree of boll weevil infestation, the total number of infested acres, climatic and topographical differences, the availability of overwintering sites, and the amount of acreage that cannot be readily treated with insecticides. It is impossible to accurately predict future conditions, so extreme scenarios were

used in the assessment of impacts on human health and nontarget species to address the possibility that eradication may take more than 3½ years in a particular program increment. In that instance, more treatments would be required on particular fields than the average number of treatments required in previously eradicated areas.

Uncertainty also exists regarding the timing of the implementation of the program in a particular program increment. This chapter describes the proposed ordering and timing of implementation of the National Boll Weevil Cooperative Control Program. One of the primary factors that may influence the ultimate sequencing of program increments is the timely passage of enabling legislation by participating States. The degree of grower support and the response of legislators will influence the timely passage of legislation. Once enabling legislation has been passed, a positive grower referendum is required, followed by appropriation of Federal funds. Delays in one program increment will impact implementation of the next increment.

Another factor that will influence the actual date of implementation in a particular program increment is the time required to complete the previous program area. If conditions in the previous program area are favorable to program success, the timetable for implementation in succeeding program increments may be accelerated. If additional time is required in the previous program areas, the timetable for implementation in other areas will be delayed.

This EIS analyzes the impacts of a program increment when that program increment is reached in the implementation sequence. The exposure scenarios used to estimate the risk of systemic and reproductive health effects do not account for differences in lifetime exposures over various regions of the Cotton Belt. These differences in lifetime exposures may result from exposure to insecticides applied by growers for control of the boll weevil or other cotton pests. However, the margin of safety estimates are generated by comparing human exposure to long-term laboratory animal exposure, and thus account for the extended lifetime exposures in different areas of the country. Lifetime exposure scenarios for carcinogenic risk analysis compensate for these regional differences not only by evaluating lifetime exposure for the average expected number of treatments, but also by evaluating carcinogenic risks using the maximum number of treatments that would be expected only in the case of program failure.

Finally, political and economic conditions over the next 20 years may vary. While substantial support currently exists for the National Boll Weevil Cooperative Control Program, the potential for long-term support is not guaranteed. The potential for premature termination of the program was considered in the evaluation of carcinogenic risk analysis by using the maximum number of treatments expected in the event of program failure.

## Soils

Potential impacts on soil from boll weevil control activities include soil disturbance and erosion resulting from insecticide application equipment or mechanical destruction of cotton stalks; improvement in soil fertility resulting from crop rotation; and effects on burrowing mammals, soil microorganisms such as bacteria and fungi, and insects caused by soil disturbance or by insecticide application.

### Potential Impacts of Nonchemical Control Methods

#### Cultural Control Methods

The use of short-season cultural control methods is not expected to significantly modify the soil environment. Although cultural control methods may result in soil disruption, these effects are not expected to exceed the impacts associated with routine procedures that growers use during planting, tilling, and harvesting operations. Cultural control methods that require host destruction, such as postharvest stalk destruction and trap cropping, may increase soil erosion by removing protective plant material or by plowing under residual cotton plant material. In the Southwest and South Central program areas, where there are few natural vegetative buffers between fields and surface water features, significant soil losses may occur from runoff during heavy winter rainstorms. Cotton fields in hilly or rolling terrain may also experience increased soil loss from runoff. Less rigorous stalk destruction methods, such as mowing or shredding, may be expected to reduce erosion potential. In some situations, shredded vegetation may actually act as a light mulch. Stalk destruction techniques that require soil disturbance may also limit or disrupt populations of soil microorganisms because of soil desiccation or erosion. Larger soil organisms (for example, burrowing rodents, moles, earthworms, and insects) may be injured or killed during destruction operations, or populations may be reduced as a result of disturbed soil conditions.

Other cultural control techniques may have a beneficial influence on soil qualities. Control methods, such as crop rotation, are commonly used to improve soil fertility and reduce erosion. Crop rotation to legumes replaces soil nitrogen lost during cotton production.

#### Mechanical Control Methods

Mechanical control by mass trapping is expected to have little effect on soils. Minor soil impacts may result from vehicular and foot traffic during placement and monitoring of traps. Because the traps are placed above the ground, the traps, pesticide strips, and pheromone lures should not come into contact with the soil. The number of traps destroyed by farm equipment and the amount of plastic from broken traps left in the environment could be considered a negative impact.

### Sterile Insect Release

The release of sterile insects is not expected to significantly impact soils because no portion of the boll weevil life cycle occurs in soils. Only minor soil impacts may result from vehicular and foot traffic associated with monitoring of pheromone traps.

## Potential Impacts of Chemical Control Methods

Impacts on the soil from chemical control methods can be direct or indirect. A direct impact of chemical treatment would be alteration of the soil's chemical or physical characteristics to the extent that the soil's ability to support a plant community is decreased. Indirect effects would include losses of soil microorganisms and higher orders of animals that influence soil characteristics. The productivity of a soil is influenced, in part, by the actions of insects, earthworms, and burrowing animals, that can improve soil granulation, transfer, aeration, and drainage (Buckman and Brady, 1969). Adverse impacts on microorganisms would also affect soil nutrient levels because microorganisms break down nutrients in rocks and soils to the molecular level for uptake by vegetation. Insecticides applied at normal or recommended application rates do not cause a long-term reduction in soil fertility. However, excessive amounts of organophosphates have been shown to inhibit soil bacteria nitrifiers (Bollen, 1961).

Leaching of insecticides from soil is a potential impact of chemical controls. The mobility of insecticides in soils is dependent on the interaction of the chemicals with all soil components (minerals, organic matter, and microorganisms) and plants. Movement through the soil depends on the relative rates and routes of water seepage, adsorption, degradation, and dilution.

The compaction and erodability of soils are independent of chemical treatment of cotton fields for boll weevil suppression or eradication. These soil characteristics would not be affected by insecticide application. Because the boll weevil eats only the cotton blooms and bolls, the cotton plant is relatively unharmed and serves to inhibit erosion. Plant cover protects the soil from the drying effects of the sun, and plant root systems retain soil that may otherwise be eroded by sun and wind action.

It is important to note that organophosphate insecticides (malathion, methyl parathion, azinphos-methyl, and chlorpyrifos) are relatively nonpersistent in the environment. These insecticides persist from only a few hours through several weeks to months (Doull et al., 1980). In comparison, other nonprogram pesticides have soil half-lives of more than 1 year. Appendix B describes the hazards and risks of using the insecticides analyzed for the National Boll Weevil Cooperative Control Program.

### Malathion

In soil, malathion is broken down relatively quickly by hydrolysis and by the action of soil microorganisms, such as *Pseudomonas* and *Trichoderma* (Matsumura and Boush, 1966); its soil half-life is 3 days

(according to a personal communication between Tim Mulholland, LABAT-ANDERSON Incorporated and Charles Galley, American Cyanamid, August 1990). Malathion's degradation products also have short half-lives (Curley and Donohue, 1986). Malathion has a low vapor pressure and does not volatilize to any discernable extent. It does not adsorb well to inorganic soil particles, although it binds tightly with organic matter. Most cotton fields are in soils rich with organic matter, which reduces the probability of malathion leaching from cotton field soils. There are some indications that malathion is very mobile in loamy sand and loam soils. However, based on its rapid degradation and reported octanol-water partition coefficient, malathion is not expected to leach to groundwater, especially in soils with high organic content (NLM, 1988). The high octanol-water partition coefficient indicates that the insecticide is much less soluble in water than in an organic solvent.

Inorganic degradation may be more important in alkaline soils with lower organic content, such as Aridosols or Entisols. Aridosols are dominant in the Southwest program area, and Entisols are common in the southern portions of the South Central and Southeast program areas.

In laboratory studies, malathion was slightly toxic to the bacterium *Nitrobacter* sp. (Bollen, 1961), but caused complete inhibition of the bacterium *Nitrosomonas* sp. (Garretson and San Clemente, 1968). Malathion applied to soils did not affect the growth of several fungi or their ability to degrade other pesticides (Anderson, 1981). Malathion application to a forested watershed caused short-term effects on microarthropods and no observed effects on bacteria, fungi, earthworms, or snails. Though populations of some soil insects and arachnids may be reduced by malathion, such populations would not be significantly altered (Giles, 1970). However, there is controversy about the long-term effects of insecticides on microarthropods—a complex situation because the balance of microarthropod populations is dependent on rainfall, predation, reproductivity, quantity and quality of food, and competition, as well as the application of pesticides (Giles, 1970). No significant alteration of earthworm population density from aerial spraying of malathion has been found in field studies (Giles, 1970).

**Azinphos-methyl**

Azinphos-methyl does not appear to be persistent in the soil environment, with a soil half-life of approximately 12 days (NLM, 1988). In soils biodegradation is the primary degradation pathway. Azinphos-methyl is adsorbed to soil, making it relatively immobile and not subject to leaching. This insecticide has an extremely low vapor pressure and would not volatilize to any discernible extent. Azinphos-methyl appears to be more persistent on plants than the other organophosphate insecticides proposed for use in this program.

Field studies have shown that azinphos-methyl, when used at recommended rates, causes only limited mortality to spiders (Culin, 1981; as cited in USDA, 1985). In a laboratory study, application of

azinphos-methyl showed no significant effect on the mortality or fecundity of earthworms (Hopkins and Kirk, 1957).

**Diflubenzuron**

The degradation of diflubenzuron in soil appears to be rapid. Technical grade diflubenzuron (the active ingredient as manufactured) at a soil concentration of 1 part per million (ppm), initially present as particles 2 microns in diameter, has a soil half-life of ½ day to 1 week (EPA, 1979). Another study (EPA, 1979) reports that 16 percent of the applied diflubenzuron may carry over to the next growing season. Use of these data yields a calculated soil half-life of approximately 20 weeks. The soil degradation of diflubenzuron, as with most pesticides, is a function of temperature; degradation rates are higher at higher temperatures. Diflubenzuron has a low water solubility and readily adsorbs to organic material. Thus, it is relatively immobile in organic soils and has minimal leaching potential. Diflubenzuron is photochemically stable.

A laboratory study determined that diflubenzuron and its metabolites were nontoxic to and degraded by soil fungi. Although one of the metabolites was lethal to *Salmonella*, field conditions would likely cause lower concentrations of the metabolite, which would result in a diminished toxicity to soil bacteria (Seuferer et al., 1979). The use of diflubenzuron does not severely affect beneficial populations of soil mites. The total population of mites after diflubenzuron application was similar to the original population; reduction of individual species of mites was compensated by increases in other mite species (Marshall, 1979).

**Methyl Parathion**

Methyl parathion is relatively immobile in sandy loam, silty clay loam, and silty loam soils. These soil types are commonly planted with cotton. Technical methyl parathion biodegrades rapidly at insecticidal concentrations, with a soil half-life of 5 days (Knisel et al., 1987). It is only slightly soluble in water (60 milligrams per liter (mg/L) at 25°C), thus reducing the likelihood of leaching. Methyl parathion has a vapor pressure lower than malathion and does not volatilize to any noticeable extent. One study determined that methyl parathion is relatively nontoxic to earthworms at normal application rates (Whitten and Goodnight, 1966). The formulation considered for use in the National Boll Weevil Cooperative Control Program is microencapsulated and has degradation rates and soil mobility similar to technical methyl parathion.

**Chlorpyrifos (in Pheromone Traps)**

The average soil half-life for chlorpyrifos in 10 different soils at 25°C is 68 days (Dow, undated). Because of the strong adsorption properties of chlorpyrifos to organic matter, it tends to adsorb to settled and suspended organic matter in the water column; therefore, it is unavailable for hydrolysis in water or in soil. Chlorpyrifos is very slightly susceptible to volatilization from soil. Because chlorpyrifos is strongly partitioned toward organic matter, it is readily adsorbed to soil and is resistant to leaching from soil by water. Chlorpyrifos is subject to photolysis and may have a minimum half-life of 30 days during periods of maximum insolation. Microbial action is the primary method of

chlorpyrifos degradation. Because chlorpyrifos degrades rapidly in soil, its impact on microorganisms would be limited in magnitude and duration (Dynamac Corporation, 1984).

Because chlorpyrifos will be used only in traps, soil exposure, and thus impacts to soil, would be minimal. The traps would protect the insecticide from rain and prevent leaching.

**Propoxur (in Pheromone Traps)**

Propoxur is relatively persistent in terrestrial systems. In sand, 25 percent was lost in 100 days. However, almost none was lost from silt-loam soil after 6 months (NLM, 1988). Propoxur is highly soluble in water and is slightly adsorbed by organic matter. Propoxur may be moderately adsorbed to soils with high clay contents. Microorganisms are the primary means for degrading propoxur in soils and are thus not significantly affected by exposure to propoxur.

Because propoxur will be used only in traps, soil exposure and thus impacts to soil would be minimal. The traps would protect the insecticide from rain and prevent leaching.

## Potential Impacts of Alternatives

### No Action

Under the no action alternative, growers would continue to plan and implement their own boll weevil controls, with no APHIS involvement. The Cooperative Extension Service or Agriculture Research Service would possibly provide technical assistance or support for boll weevil control, but the extent of their cooperation is undetermined. This alternative presents an unknown impact on soils because it is not known what control measures growers may choose in the future.

Current use of cultural control methods is less than would be expected under the National Boll Weevil Cooperative Control Program. For this reason, the impacts associated with the use of cultural control methods could be less than anticipated under the other alternatives. Site-specific impacts, including increased erosion potential, might still occur on fields where growers use these methods.

Growers currently do not use mass trapping or sterile insect release to control the boll weevil. It also is not known what chemicals individual growers may use, how much and when the chemicals would be applied, and what operational and mitigation measures might be used to safeguard sensitive areas or organisms. Because these factors are unknown, the no action alternative could present higher toxic loadings of pesticides than either the eradication or suppression alternatives.

Some insecticides used by growers for boll weevil control may be more persistent in the soil and have a higher toxicity to soil organisms than those proposed for use in the National Boll Weevil Cooperative Control Program. The increased persistence of these chemicals may result in decreased soil fertility and a greater adverse impact on soil organisms than under the other alternatives. Additionally, some of these

chemicals may not adsorb to soil and organic matter as strongly as the insecticides proposed for use in the cooperative program, thus increasing the potential for runoff contamination. Depending on the chemicals used, there may be a greater potential for leaching into groundwater resources, with a corresponding impact on the environment.

Growers may also apply insecticides more frequently than the schedule proposed in the cooperative control program. Increased frequency of application may lead to accumulation of these materials in the soil, reduced capacity of soil microorganisms to reestablish themselves, and increased potential for contamination of runoff, thus affecting soil productivity.

### Beltwide Eradication Program

Under the eradication alternative (both full and limited Federal involvement), boll weevil control methods would not have a significant impact on soil or soil organisms.

Cultural control methods that involve removal of host plants may increase the risk of erosion, but this erosion potential would not be greater than that expected from other agricultural practices. Cultural control practices that involve planting rotational crops or allowing the field to lie fallow may affect soil fertility or erosion potential, but the negative or positive aspect of this effect would depend on the replacement vegetation.

Mechanical control or the release of sterile boll weevils would have no significant impacts on soils or soil organisms.

All four insecticides proposed for foliar application are rapidly degraded and strongly adsorb to soil and organic matter. Soil organisms could be temporarily affected by these chemicals but should soon return to pretreatment levels.

### Beltwide Suppression Program

Under the full Federal involvement suppression alternative, boll weevil control methods would not have a significant impact on soil or soil organisms. With limited Federal involvement, however, it would be more difficult to ensure that growers used the preferred chemical controls.

The impact of the use of cultural controls is identical to impacts under the eradication alternative. Mechanical control and the release of sterile insects would not be used under this alternative.

The short-term effect of chemical controls on soil microorganisms may be expected to be even less than under the eradication alternative because of the reduced frequency of application. In the long term,

however, repeated applications may be needed every season, which could affect soil microorganisms.

## Vegetation

Potential impacts of boll weevil control activities on adjacent vegetation are limited to indirect effects from cotton pest displacement due to loss of habitat and indirect effects on plant reproduction due to a reduction in insect pollinators.

### Potential Impacts of Nonchemical Control Methods

#### Cultural Controls

No direct effects on adjacent nontarget vegetation are expected from cultural control methods. Destruction of adjacent crops and vegetation caused by mowing and discing equipment used for stalk or plant destruction is not anticipated. Cotton fields are readily accessible to heavy equipment required in normal planting and tilling operations.

Some indirect impacts on nontarget vegetation may be expected as a result of the use of cultural control methods.

Methods that involve host destruction or elimination, such as postharvest stalk destruction, trap cropping, and crop rotation, may drive some cotton pests that are not host-specific into adjacent crops. Examples of potential displacement include lygus bugs into beans, corn, and alfalfa; armyworms into corn, peanuts, alfalfa, and soybeans; cotton bollworms into corn; and tobacco budworms into tobacco and summer squash.

Cultural control methods that involve host destruction may also secondarily influence adjacent vegetation because of increased erosion or other adverse impacts that result from physical disruption of the soil.

#### Mechanical Control Method

Mechanical control by mass trapping is expected to have no effect on surrounding nontarget vegetation. Pheromone traps are located within or on the immediate perimeters of cotton fields, and monitoring does not require disturbance of adjacent vegetation.

#### Sterile Insect Release

Control by sterile insect release is expected to have little impact on adjacent nontarget vegetation. Because the boll weevil is highly host-specific, increased damage from feeding of sterile weevils would be limited to cotton plants in most areas. In the extreme southern portion of the Cotton Belt (including south Texas and Florida), alternate hosts of the family Malvaceae (hibiscus) may sustain some feeding damage from the release of sterile insects. However, the period of exposure and extent of damage would be limited because the released boll weevils would die without reproducing.

### Potential Impacts of Chemical Control Methods

Though chemical control methods would protect vegetation by removing the boll weevil and other nontarget plant-eating insects, program insecticides could potentially indirectly affect plant reproduction by reducing insect pollinator populations. Additionally, program insecticides could be directly toxic to vegetation (phytotoxicity). However, application volume would be so low with ultra low volume (ULV) equipment that phytotoxicity should be insignificant.

#### Indirect Effects Caused by the Decline of Insect Pollinators

Malathion, azinphos-methyl, and methyl parathion are highly toxic to honey bees (diflubenzuron is relatively nontoxic to bees). If populations of insect pollinators, such as honey bees, are reduced as a result of the use of these insecticides, the propagation of nearby crops and vegetation could be adversely affected. The magnitude of this impact would depend on the number of pollinators killed and their importance to the propagation of plants in the area. However, substantial bee kills and adverse effects on vegetation usually would be avoided because beekeepers would be notified before treatment began to give them time to move their hives away from fields being sprayed. (The relative toxicity of program insecticides to honey bees is discussed in section B5 of appendix B.)

#### Direct Effects

The insecticides used in the National Boll Weevil Cooperative Control Program are registered for use on a variety of vegetation and crops, including many found near cotton fields. If the chemicals are administered correctly and at appropriate levels, they do not appear likely to injure vegetation. Although limited drift of insecticides onto nearby crops and vegetation may occur during aerial applications of an insecticide, none of the insecticides used is known to be absorbed readily through the leaf surface (EPA, 1986b; Harding, 1980; Chemagro Research Staff, 1974). Thus, the low level of insecticide likely to settle on adjacent vegetation is not likely to be phytotoxic. (Concerns about human consumption of insecticide residues on food crops near cotton fields are addressed in sections B3 and B4 of appendix B.) To understand potential long-term effects on vegetation, additional studies are needed on the uptake, distribution, and metabolism of these chemicals in plants, trees, and crops.

### Potential Impacts of Alternatives

#### No Action

The no action alternative involves growers continuing their current practices, with no APHIS involvement. The impacts of this alternative on nontarget vegetation are unknown because it is not known what control measures growers may use.

Current use of cultural control methods is less than would be expected under the National Boll Weevil Cooperative Control Program. For this reason, the impacts associated with the use of cultural control methods

could be less than anticipated under the other alternatives. Site-specific impacts, including potential migration of cotton insect pests into adjacent fields to alternate host vegetation, might still occur on fields where growers use these methods. Growers currently do not use mass trapping or sterile insect release for boll weevil control.

It is also unknown what chemicals individual growers may use, in what quantity and how frequently the chemicals may be applied, or what operational and mitigation measures may be used to protect sensitive areas or organisms. Because these factors are unknown, the no action alternative could produce higher toxic loadings of insecticides than either the eradication or the suppression alternative. Some chemicals that growers use to control the boll weevil may be more phytotoxic than those proposed for use in the cooperative control program. These chemicals also may not be approved for use on adjacent food crops. Without adequate mitigation, drift from the application of these insecticides may result in contaminating residues on adjacent crops.

Growers may also apply insecticides that are more toxic to insect pollinators, thus increasing the potential impact on plant reproduction in species dependent on these pollinators. Growers also may fail to notify nearby apiarists (beekeepers), and nearby hives may be lost.

**Beltwide Eradication Program**

Under the eradication alternative (both full and limited Federal involvement), boll weevil control methods would not have significant impacts on nontarget vegetation.

Cultural control methods that involve the removal of host plant material may increase the risk of driving secondary pest species into nearby alternative host crops. These impacts, however, would be temporary because host plant material would be destroyed at the end of the growing season.

Cultural control practices that involve planting rotational crops or allowing the field to lie fallow are not expected to significantly affect adjacent vegetation, provided the field is still managed; however, unattended fields may allow noxious weed species to infiltrate adjacent vegetation.

Mechanical control or the release of sterile boll weevils would have no significant impact on nontarget vegetation.

All four insecticides proposed for foliar application generally are not phytotoxic, and no significant impact on adjacent vegetation is expected from spray drift. Effects on plant reproduction may be expected in vegetation dependent on bee pollinators if a substantial number of bee pollinators are killed from insecticide spraying. However, this effect would be temporary because foraging bees would continue to reenter the fields affected by direct spray or spray drift. Diflubenzuron is

relatively nontoxic to insect pollinators, and its use would have no significant impact on pollinator-dependent plants.

Notification of nearby apiarists would be required if hives are located close to cotton fields requiring treatment, thereby mitigating the indirect effects on pollinator-dependent vegetation.

### Beltwide Suppression Program

Under the suppression alternative (both full and limited Federal involvement), boll weevil control methods would not have a significant impact on nontarget vegetation.

The impacts of the use of cultural controls are identical to impacts under the eradication alternative. Mechanical control and the release of sterile insects would not be used under this alternative.

The short-term effects on pollinator-dependent vegetation caused by the reduction in pollinators from chemical applications may be less than under eradication because of the reduced frequency of application. Under both suppression alternatives, however, treatment could be required every season. Under limited Federal involvement, growers may use a chemical more toxic to bee pollinators than those analyzed in this EIS.

## Water Quality

Water quality is directly related to the geology and geography of the surrounding area. Soil types, vegetative cover, total precipitation, and topography determine the quality of the ground- and surface water in a drainage basin. The primary impact under any program alternative will be the potential for insecticides to reach humans or aquatic species through surface water. Insecticides can also reach groundwater through leaching; however, the analysis indicates that proposed insecticides do not leach to any significant degree.

### Potential Impacts of Nonchemical Controls

#### Cultural Control Methods

Cultural control methods that require the removal of vegetative cover and cotton plant debris may contribute to the sedimentation of inland waters through erosion of topsoil and transport of surface runoff. Sedimentation may be greater in the northern areas of the Cotton Belt, where hilly or rolling terrain increases runoff. The impact of these cultural controls should not be significantly greater than impacts expected from normal cultivation and harvest activities. The increased loading of streams may temporarily increase the turbidity in some nearby aquatic systems, which could cause temporary, localized shifts in the aquatic community species composition.

Cultural control methods that result in permanent removal of the cotton crop from areas that cannot be treated effectively may improve the

water quality of nearby streams by reducing erosion potential of agricultural lands.

### Mechanical Control

Mechanical control by mass trapping is not expected to impact aquatic systems and habitats. Traps, insecticide strips, and pheromone lures are not expected to come into physical contact with free-flowing or standing water. For this reason, mass trapping may be used in cotton fields adjacent to sensitive aquatic habitats.

### Sterile Insect Release

The release of sterile boll weevils will not affect aquatic systems. No portion of the boll weevil's life cycle occurs in water. Thus, sterile insect release may be used to control boll weevils in areas adjacent to sensitive aquatic habitats.

## Potential Impacts of Chemical Controls

This EIS uses two modeling programs to examine the potential of program insecticides to affect water quality: GLEAMS and EXAMS.

### Leaching Analysis—GLEAMS Model

The Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model, (Leonard et al., 1987; Leonard et al., 1988) was used to determine the characteristics of runoff and leachate from fields treated with insecticides considered for use in this EIS. The application of the GLEAMS model to the boll weevil program is within the realm of expectations for the model, that is, evaluating the effects of agricultural practices on nonpoint pollutant loads. GLEAMS provided information on insecticide concentrations retained in soil, runoff (both in sediment and water), and leachate for the following 10 representative site/soil combinations across the Cotton Belt:

- Alabama: Decatur silt loam
- Arizona: Shontik sandy loam
- Arizona: Trix clay loam
- Georgia: Cowerts loamy sand
- Mississippi: Dubbs very fine sandy loam
- Mississippi: Sharkey and Alligator clays
- Texas, Coastal: Orelia sandy clay loam
- Texas, Coastal: Victoria clay

- Texas, Rolling Plains: Miles fine sandy loam
- Texas, Rolling Plains: Abilene clay loam

Sands, silts, and clays are soil classifications named for the dominant soil sediment type. Loam soils have similar proportions of sand and silt with up to 40 percent clay particles. In clay soils, more than 40 percent of the particles are less than 0.0002 millimeters (mm) long. A soil must have more than 85 percent of particles greater than 0.05 mm to be classified as a true sand; with increasing proportions of silt and clay, the soil class would be modified to a loamy sand, sandy loam, sandy clay loam, and loam, respectively (Brady, 1974). Appendix B, section B8 describes this modeling approach and the results in greater detail. (Appendix B, section B8, also describes 2-, 10-, and 100-year storms in greater detail.) Results show that there is only minimal leaching of the four chemicals proposed for foliar application during simulated 2-year storms. The short half-lives of the insecticides and their strong adsorbance to organic matter and soil particles minimize their potential to migrate into groundwater.

Because the four program insecticides are not prone to leaching into the groundwater, they present extremely small risks to people who drink groundwater. In Alabama, for example, it is expected that extremely small quantities of azinphos-methyl and malathion may leach from cotton fields after major storms. If it were possible for a person to drink this leachate, he or she would receive doses of azinphos-methyl and malathion 10,000 times *less* than the extreme doses that the human exposure analysis found to be safe (appendix B, section B3). In the modeled worst case of insecticide leaching in the Cotton Belt (Arizona Shontik sandy loam after a 100-year storm), the doses that a person might receive from drinking 2 liters of this particular leachate would still be 1,000 times less than the extreme doses that the human exposure analysis found to be safe. Considering that the leachate will be diluted when it reaches the aquifer, it is reasonable to state that there will be no risk to humans or other organisms from cotton field leachate originating in fields within the National Boll Weevil Cooperative Control Program.

According to the models, most of the insecticide residues in the environment will occur as dissolved molecules in surface water runoff. Approximately 60 to 80 percent of the residues in runoff were found dissolved in surface water; the remaining portion was carried on or in suspended solids (silt) in the surface water.

Insecticides that are attached to suspended solids will be less available to organisms ingesting the contaminated water. These suspended solids, which will eventually settle, could adversely affect benthic organisms. The insecticides attached to sediments may be released slowly over time at concentrations too low to cause any significant effect. However, insecticides dissolved in water will be immediately available to organisms that consume or live in the water.

The 2-year, 10-year, and 100-year storms were modeled successively. Degradation of the insecticides before the storms reduced the soil concentrations. After the 2-year storm, minimal residues were available for migration during the 10-year and 100-year storms. Therefore, the greatest risk, as modeled, was from the 2-year storm. These risks are discussed in the nontarget species risk analysis section of this chapter.

An analysis of the results calculated by GLEAMS illustrates that large (10- or 100-year) storms do not present risk to nontarget species. The field runoff from these storms is of sufficient volume to dilute the insecticides in the water to concentrations that do not pose a risk to aquatic wildlife. Additionally, the frequency of these events is rare.

The impacts an insecticide may have on aquatic life is a function of the following six variables:

- Volume of precipitation produced by a storm
- Volume of field runoff
- Insecticide concentration in field runoff
- Quantity of insecticide washed into a stream or river
- Stream volume and flow, which dilute insecticide concentrations
- Length of time the insecticide is in contact with the receiving organism

Maximum impacts to aquatic wildlife are assumed to occur closest to the point of runoff discharge. The dilution of insecticide concentrations that will occur immediately downstream of the point of discharge may be sufficient to reduce insecticide concentrations to safe levels. Therefore, smaller streams close to cotton fields are at greater risk. Small streams in the Southeast program area are more susceptible than most other surface waters.

### Runoff Analysis—EXAMS Model

The Exposure Analysis Modeling System (EXAMS) model (Burns et al., 1982) was used in this EIS to determine the effects of agricultural runoff containing insecticides considered for use in the National Boll Weevil Cooperative Control Program. (The latest version of the model, EXAMS II, was used in this analysis.) This model provides information on the transport and fate of chemical pollutants in surface water. Appendix B (section B8) describes this modeling approach in greater detail.

Five river basins were modeled: the Flint in Georgia, the Gila in Arizona, the Red in Texas and Oklahoma, the Sunflower in Mississippi, and the Tennessee in Alabama and Tennessee. Application scenarios

for the proposed eradication and suppression programs were included in calculations, as well as data on 10 soil types, rainfall statistics, hydrology, and erosion information. Hypothetical 2-year storms were used to study worst case situations.

During preliminary modeling to estimate the concentrations of insecticides in streams and rivers, a simple, worst case scenario was considered. GLEAMS estimated insecticide runoff from cotton fields in mass per acre. The cotton acreage of counties within the modeled river basins was used with the GLEAMS runoff data to determine the amount of insecticide runoff for an entire river basin. Each basin was divided into 16 sub-basins to correspond with the 16 aqueous compartments of EXAMS, and the proportion of basin loading into each compartment was determined. The volume of the main rivers after a 2-year storm was estimated using precipitation and streamflow data. After establishing the chemical characteristics of the insecticides, the mass of insecticide entering the river, and the volume of the river, EXAMS II was run to estimate the maximum concentrations of insecticide in the rivers. The results were then used in the aquatic wildlife risk analysis (found later in this chapter).

The following five variables are important when evaluating the conservative results produced by EXAMS II:

- Acreage of fields in the basin that are sprayed and the timing of the spraying
- Application schedule
- Application rate
- Presence of dams, drainage ditches, and other flow modifications
- Length of tributaries in the river basin

The modeling scenarios for all rivers, with the exception of the Tennessee River, assumed that the entire basin would be sprayed at one time and that precipitation would occur over the entire basin. In reality, storms can be localized within portions of a basin; and it may take approximately 1 week to spray a basin. The modeling scenario for the Tennessee River assumed that the entire basin would be sprayed over 3 consecutive days. The actual concentrations of insecticide in rivers after a storm are likely to be lower than predicted because of localized storms and insecticide degradation in parts of the basin sprayed before others.

Variations in the application schedule are also important because circumstances may exist where very few fields in a given drainage basin are sprayed. The modeling scenarios assumed the highest application frequency. The runoff from a field, as predicted by GLEAMS, was assumed to flow unimpeded and undegraded into the main river

basin. However, the presence of obstructions into flow, such as dams and drainage ditches, can trap sediments and diminish the downstream flow of insecticide-laden runoff.

The EXAMS modeling showed that none of the proposed chemicals will be present in rivers except during direct accidental spraying of surface water or during precipitation events that yield runoff. When the insecticide concentrations in runoff are considered along with the sporadic and transient runoff episodes and the conservative assumptions used to model the concentrations in rivers, the water quality of rivers is not expected to be significantly affected by the National Boll Weevil Cooperative Control Program. A comprehensive review of each chemical proposed for ground or aerial application can be found in appendix B, section B8.

The impacts of the National Boll Weevil Cooperative Control Program on ponds also were considered. Farm ponds have limited dilution potential, which may cause acute impacts if insecticides are applied directly to farm ponds. Runoff to ponds would have less potential than direct spraying to raise insecticide concentrations in the pond because the insecticide would already be diluted.

The potential impacts of insecticides on aquatic organisms must be related to the normal annual cycle of the pond. During the summer months, and particularly in the late summer, higher water temperatures will greatly influence potential impacts by increasing the metabolism of aquatic organisms, which, in turn, will increase their food intake, and thus their insecticide intake if the food is contaminated. If food is unavailable, an organism may draw on its fat reserves; and previously absorbed insecticides stored in the fatty tissues will be metabolized when the fat is metabolized.

Higher water temperatures also can reduce the level of dissolved oxygen in water. Aquatic organisms depend on the oxygen dissolved in the water for their survival. At low dissolved oxygen levels, aquatic organisms can become stressed and more susceptible to disease or toxins such as insecticides.

Summer algal blooms in ponds are common. Periods of increased sunlight, nutrients, and temperature can dramatically increase the growth rate of algae. When the algal bloom declines, the decaying algal mass can drastically reduce the dissolved oxygen levels of an affected pond. As described above, this can lead to adverse impacts on the aquatic organisms, which could be exacerbated by insecticides.

Ponds are also subject to volume reduction during the summer because of increased evaporation rates and decreased precipitation, which concentrates any nonvolatile contaminants in the water. The lower volume of water in the pond also will provide less dilution potential if insecticides from drift, direct sprays, or cotton field runoff enter the pond.

## Potential Impacts of Alternatives

### No Action

The no action alternative involves the continuation of current grower practices, with no APHIS involvement. The potential impacts on water and water ecosystems are unknown because it is not known what chemicals individual growers may use, in what quantity and how often the chemicals might be applied, and what operational and mitigation measures might be used to protect sensitive areas and organisms. Because these factors are unknown, this alternative could present higher loadings of insecticide than either the eradication or suppression alternatives. In addition, the insecticides used by growers could be more mobile and have greater potential to reach groundwater and surface water.

### Beltwide Eradication Program

At both levels of full and limited Federal involvement, the eradication alternative is expected to provide slightly more potential to cause insecticide loss in runoff or percolating water than the suppression alternative. The estimated environmental concentrations (EECs) of insecticides in rivers caused by runoff from cotton fields treated under eradication range from approximately 0.1 mg per liter (mg/L) for malathion to 0.00005 mg/L for diflubenzuron (table 4-1). Slightly higher EECs for the eradication alternative are the result of different application schedules during different times of the year than the suppression alternative. No significant long-term impacts on water quality are expected under the eradication alternative; short-term impacts to nontarget aquatic organisms are discussed in the following section.

### Beltwide Suppression Program

As shown in table 4-1, the predicted EECs under the suppression alternative are slightly, but not significantly, lower than the EECs estimated under the eradication alternative.

Although the program chemicals vary in their toxicity, the suppression program is not expected to cause significant long-term impacts on water quality. Operational and mitigation measures designed to protect sensitive areas and species are presented in chapter 2.

## Nontarget Wildlife, Aquatic, and Insect Species

Potential impacts from boll weevil control activities on nontarget species include the following: temporary displacement of wildlife caused by disturbance from noise, dust, and vibration from control activities; injury or death from heavy equipment; and potentially significant toxic systemic and reproductive effects on terrestrial and aquatic species from the use of chemical controls.

**Table 4-1. Dissolved Concentrations of Insecticides in Water—Loadings From Runoff (mg/L)**

| River systems | Malathion[a] | | Azinphos-methyl[a] | | Diflubenzuron[a] | | Methyl parathion[a] | |
|---|---|---|---|---|---|---|---|---|
| | Eradication | Suppression | Eradication | Suppression | Eradication | Suppression | Eradication | Suppression |
| Flint (GA) | 0.017 | 0.0015 | 0.00041 | 0.00040 | 0.0001 | NA | 0.00025 | 0.00021 |
| Gila (AZ) | 0.0092 | 0.0031 | 0.0029 | 0.0017 | 0.0004 | NA | 0.0002 | 0.0001 |
| Red (TX, OK) | 0.116 | 0.117 | 0.026 | 0.026 | 0.005 | NA | 0.003 | 0.003 |
| Sunflower (MS) | 0.028 | 0.027 | 0.008 | 0.006 | 0.002 | NA | 0.0004 | 0.0004 |
| Tennessee (AL, TN) | 0.00057 | 0.00046 | 0.00011 | 0.00009 | 0.00005 | NA | 0.00010 | 0.00008 |

[a] Estimated environmental concentrations.

Note: NA = Not applicable.

## Potential Impacts of Nonchemical Controls

### Cultural Control

Wildlife that reside in habitats adjacent to cotton fields may be expected to be acclimated to noise, dust, and vibration associated with agricultural activities. As a result, only a few may be expected to temporarily leave the area during cultural control activities.

Small mammals, reptiles, and insects that remain in the cotton fields during stalk destruction operations may be accidentally maimed or killed by mowing and tilling equipment. However, mortality rates from shredding would not be higher than those expected from mechanical harvesting operations.

Cultural control methods that remove or eliminate host plant material will reduce or eliminate other insect populations that depend on cotton for feeding and reproduction. Stalk destruction is a key component in controlling pink bollworms and also has been effective in reducing overwintering populations of cotton bollworms and tobacco budworms.

Some beneficial insect species may also be extirpated, or their populations may be reduced as a result of the elimination of cotton plant material. Populations of beneficial or pest insects may be directly reduced during shredding or mowing operations, or beneficial or pest species may migrate to nearby crops or habitats and infest alternate hosts. Predator species of insects and birds will relocate along with their insect prey.

### Mechanical Control

Mechanical control by mass trapping is expected to have little effect on nontarget terrestrial species. The pheromone lure contained in the trap is highly species specific and will attract only the boll weevil. Birds and larger mammals may investigate the traps out of curiosity, but they are not expected to be able to break open the traps and come into contact with the insecticide strip.

### Sterile Insect Release

The release of sterile insects is not expected to impact nontarget terrestrial species. Because no effective predators or parasites of the boll weevil exist in the Cotton Belt, release of sterile weevils will not affect the population dynamics of beneficial insects. The boll weevils primarily compete with each other for feeding and reproductive sites; therefore, the release of sterile weevils is not expected to impact the population dynamics of other pest species.

## Potential Impacts of Chemical Controls— Nontarget Species Risk Assessment

### Overview

A risk assessment, similar to that conducted to evaluate risks to human health, was conducted to evaluate the potential effects of malathion, azinphos-methyl, diflubenzuron, and methyl parathion on terrestrial and aquatic wildlife species. The methodology, which consists of hazard, exposure, and risk analysis components, is briefly described below. The results, including a discussion of effects on the cotton arthropod complex, are summarized.

The hazard analysis evaluated the toxic properties of the insecticides proposed for use in the National Boll Weevil Cooperative Control Program by summarizing the findings of laboratory and field studies. In some cases, laboratory studies of domestic species have been used because of a lack of studies specifically conducted on wildlife. The results of domestic animal studies are considered to represent the effects that would occur in the wild. Most judgments about the potential hazards of pesticides are based on the results of toxicity tests. These tests are used to determine the toxicity reference value known as the median lethal dose ($LD_{50}$), which is the dose that kills 50 percent of the test animals. Details are presented in appendix B (section B5).

The terrestrial wildlife exposure analysis calculated the exposures for a group of wildlife species representative of those typically found in areas of the United States where cotton is grown, representing a range of phylogenetic classes, body sizes, and diets. Table 4-2 lists the representative terrestrial wildlife species for the three program areas of the Cotton Belt. The aquatic species exposure analysis calculated the concentrations of insecticide in bodies of water to estimate the acute risk to fish and aquatic invertebrates. Details are presented in appendix B (sections B6 and B8).

Risk to nontarget species is a function of the hazard and exposure for each insecticide. That is, risk is a result of each insecticide's inherent toxicity and the amount of the insecticide to which the organism is exposed, either by direct contact or contamination of its food, water, and environment. The nontarget species risk analysis compares estimated acute exposures of representative species determined in the exposure analysis with acute toxicity levels found in laboratory studies. Details are presented in appendix B (section B7).

The results of the risk assessment indicate that potential impacts on terrestrial wildlife and aquatic species vary by insecticide. Malathion poses little risk to most terrestrial organisms but may pose a high risk to fish and aquatic invertebrates. Drift concentrations of azinphos-methyl present little risk to terrestrial organisms, but a direct spray of this insecticide may present moderate to high risks. For aquatic species, azinphos-methyl presents a high risk to fish and aquatic invertebrates. Drift concentrations of methyl parathion present a moderate risk to some terrestrial species, while a direct spray presents moderate to high risks. Also, methyl parathion presents moderate to high risk to

**Table 4-2. Representative Wildlife and Domestic Species**

| Representative niche | Representative species | | |
|---|---|---|---|
| | Southeast region | South central region | Southwest region |
| **Birds:** | | | |
| Insectivorous | Eastern kingbird (*Tyrannus tyrannus*) | Eastern kingbird (*Tyrannus tyrannus*) | Western kingbird (*Tyrannus verticalis*) |
| Herbivorous | Northern bobwhite quail (*Colinus virginianus*) | Northern bobwhite quail (*Colinus virginianus*) | Gambel's quail (*Callipepla gambelii*) |
| Piscivorous | Belted kingfisher (*Megaceryle alcyon*) | Belted kingfisher (*Megaceryle alcyon*) | Belted kingfisher (*Megaceryle alcyon*) |
| Carnivorous | American kestrel (*Falco sparverius*) | American kestrel (*Falco sparverius*) | American kestrel (*Falco sparverius*) |
| **Mammals:** | | | |
| Small herbivorous | Cotton mouse (*Peromyscus gossypinus*) | Deer mouse (*Peromyscus maniculatus*) | Deer mouse (*Peromyscus maniculatus*) |
| Medium herbivorous | Eastern cottontail rabbit (*Sylvilagus floridanus*) | Eastern cottontail rabbit (*Sylvilagus floridanus*) | Desert cottontail rabbit (*Sylvilagus audubonii*) |
| Large herbivorous | White-tailed deer (*Odocoileus virginianus*) | White-tailed deer (*Odocoileus virginianus*) | Mule deer (*Odocoileus hemionus*) |
| Carnivorous | Red fox (*Vulpes fulva*) | Coyote (*Canis latrans*) | Coyote (*Canis latrans*) |
| **Reptiles:** | | | |
| Snake | Eastern garter snake (*Thamnophis sirtalis sirtalis*) | Western diamondback rattlesnake (*Crotalus atrox*) | Western diamondback rattlesnake (*Crotalus atrox*) |
| **Amphibians:** | | | |
| Toad | Fowler's toad (*Bufo woodhousei fowleri*) | Rocky Moutain toad (*Bufo woodhousei woodhousei*) | Red-spotted toad (*Bufo punctatus*) |
| **Invertebrates:** | | | |
| Insect | Honey bee (*Apis mellifera*) | Honey bee (*Apis mellifera*) | Honey bee (*Apis melifera*) |
| **Domestic animals** | Cow, chicken, dog | Cow, chicken, dog | Cow, chicken, dog |

aquatic invertebrates. Diflubenzuron presents little risk to terrestrial organisms but may pose a moderate to high risk to aquatic invertebrates. All chemicals pose a higher risk to bees than other terrestrial species. Operational procedures call for notifying local beekeepers of program procedures and treatment intervals and measures they can use to protect their bees. (See the discussion of standard operating procedures and mitigation measures in chapter 2.)

### Nontarget Species Hazard Analysis

***Malathion.*** Malathion is moderately toxic to mammals. The lowest oral $LD_{50}$ value for rats is 1,375 mg/kg (Gaines, 1960; as cited in Dobroski and Lambert, 1984). The lowest oral $LD_{50}$s for cattle, rabbits, and mice are 53, 250, and 507 mg/kg, respectively (NIOSH, 1987). No effects on wildlife were observed in a field study that included population censuses, carcass counts, and tissue residue analyses in areas sprayed at 0.425 lb active ingredient per acre (a.i./acre), a rate lower than the proposed program rate. (McEwen et al., 1972; as cited in Dobroski and Lambert, 1984).

The reported oral $LD_{50}$ of malathion for chickens is 150 to 850 mg/kg (EPA, 1975). The oral $LD_{50}$s are 167 mg/kg for pheasants and 403 mg/kg for horned larks (Hudson et al., 1984). The $LD_{50}$ for mallards is 1,485 mg/kg (Smith, 1987).

High doses of malathion are known to inhibit brain cholinesterase (ChE) activity in quail (Meydani and Post, 1979; as cited in Dobroski and Lambert, 1984). The minimum application rate to produce this effect has not yet been conclusively determined. The Fish and Wildlife Service (1986) has suggested further research in this area.

Malathion is highly toxic to bees and can cause severe losses if bees are present at the time of treatment. The 48-hour $LD_{50}$ in honey bees (*Apis mellifera* L.) is 0.000709 mg/bee for exposure to malathion dust (Atkins et al., 1973). Ultra-low-volume (ULV) application of malathion extends the residual life of the insecticide and, compared to treatments using diluted malathion, increases malathion toxicity to bees by a factor of four (Levin et al., 1968; Johansen, 1979; both as cited in Dobroski and Lambert, 1984). Also, aerial application of pesticides has been shown to be more hazardous than ground-based treatments, and granular applications have been determined to provide the highest margin of safety for bees, according to studies cited in Dobroski and Lambert (1984).

Fish sensitivity to malathion depends on species, water quality, temperature, and exposure times (EPA, 1975). In general, malathion seems to have a moderate level of toxicity to some species of fish. Species such as carp may tolerate this insecticide at the normal application rate used in mosquito control, whereas others, such as striped bass and mosquito fish, may suffer moderate to high mortality.

The aquatic invertebrates most acutely sensitive to malathion are scuds, stoneflies, and caddisflies. Field studies support the finding that scuds are sensitive to malathion. However, some studies have shown differences between laboratory and field results. For example, laboratory populations of shrimp have been shown to be highly sensitive to malathion (Hunsen et al., 1973; as cited in Dobroski and Lambert, 1984), while field studies of insecticide exposure to various crustacean species, including shrimp and plankton, showed no effect on the organisms at mosquito control levels, which are lower than program application rates (Tapatz et al., 1974; Wall and Marganian, 1971; both as cited in Dobroski and Lambert, 1984).

Malathion is toxic to Fowler's toad and western chorus frog tadpoles, whose 96-hour median lethal concentrations ($LC_{50}$s) are 0.420 and 0.20 mg/L, respectively (Mayer and Ellerseick, 1986).

***Azinphos-methyl.*** Azinphos-methyl is highly toxic to mammals. The acute oral $LD_{50}$s for mice and guinea pigs are 15 (NLM, 1988) and 80 mg/kg (Smith, 1987), respectively.

Azinphos-methyl is moderately toxic to birds (EPA, 1986c). Acute oral toxicity $LD_{50}$s are 136 mg/kg for mallard ducks and 60 mg/kg for bobwhite (Hudson et al., 1984). Red-winged blackbirds have an acute oral $LD_{50}$ of 8.0 mg/kg (Shafer, 1983). Chickens have an acute oral $LD_{50}$ of 277 mg/kg (NIOSH, 1987).

In field tests, azinphos-methyl did not frequently prove toxic to birds. For instance, in one test, caged bobwhite sprayed by a ULV application of 1 lb a.i./acre showed no symptoms of toxicity in periodic observations during the month following application (Nelson and Shipp, 1967; as cited in Anderson et al., 1974). Penned pheasants showed no harmful effects after treatment with a diluted spray containing azinphos-methyl at the relatively high rate of 5 lb a.i./acre. The reproductive success of pheasants sprayed with azinphos-methyl did not differ significantly from that of control birds (DOI, 1967; as cited in Anderson et al., 1974).

Evidence indicates that azinphos-methyl does not accumulate in aquatic environments to levels that may be detrimental to waterfowl. Five mallard ducks placed in 0.0315-acre ponds that had been sprayed six times with azinphos-methyl at the rate of 0.4 lb a.i./acre were active and healthy and developed normally (DOI, 1963; as cited in Anderson et al., 1974).

Azinphos-methyl is highly toxic to honey bees. Contact toxicity is 0.000063 mg/bee, and the acute oral $LD_{50}$ is 0.00015 mg/bee (Stevenson and Walker, 1976; as cited in Lambert, 1985). Field studies reflect this high toxicity.

Fish species vary greatly in their response to azinphos-methyl. Available data show azinphos-methyl to range from very highly toxic to

moderately toxic to freshwater fish, with $LC_{50}$ values ranging from 0.00036 to 4.27 mg/L, depending on species tested, with most values in the very highly toxic range (less than 0.1 mg/L) (EPA, 1986d). Field studies have demonstrated that azinphos-methyl application to farm ponds may result in significant mortality to many fish species, including green sunfish, bluegills, crappies, threadfin shad, largemouth bass, and redear sunfish (Meyer, 1965; Campbell, 1968; as cited in Anderson et al., 1974). Bluegills, sunfish, trout, and bass are considerably more sensitive to azinphos-methyl than are black bullhead, channel catfish, or goldfish (Anderson et al., 1974).

Azinphos-methyl is very highly toxic to freshwater aquatic invertebrates, with 96-hour $LC_{50}$ values varying from 0.00010 to 0.022 mg/L, depending on the species tested (Nebeker and Gaufin, 1964; Gaufin et al., 1965; Jensen and Gaufin, 1966; Sanders and Cope, 1968; Sanders, 1969, 1972; all as cited in EPA, 1986d).

Zooplankton populations, especially copepods, may be substantially reduced by azinphos-methyl. However, Meyer (1965) reports that they quickly return to pretreatment levels.

Western chorus frog tadpoles, with a 96-hour $LC_{50}$ of 3.20 mg/L, are more tolerant of azinphos-methyl than Fowler's toad tadpoles, which have a 96-hour $LC_{50}$ of 0.109 mg/L (Mayer and Ellerseick, 1986).

***Diflubenzuron.*** Diflubenzuron has a low toxicity to mammals. The acute oral $LD_{50}$ for rats is greater than 4,640 mg/kg (EPA, 1987). Field applications of diflubenzuron to a boreal forest at application rates of 0.0625, 0.125, and 0.25 lb/acre showed no adverse effects on small mammals (Brown and Dimond, 1976).

Diflubenzuron has a low toxicity to birds. For bobwhite and mallards, the acute oral $LD_{50}$ is greater than 5,000 mg/kg (EPA, 1987). The low toxicity of diflubenzuron is supported by field observations. In an experimental aerial application of diflubenzuron at 0.0783 lb a.i./acre on a 600-acre plot, no effects on forest songbirds were observed (Buckner et al., 1975).

Diflubenzuron is considered relatively nontoxic to honey bees, with an acute toxicity of greater than 0.1148 mg/bee (EPA, 1987). Field observations support this. No effects were observed in colonies of domestic honey bees in the path of the experimental aerial application discussed in the preceding paragraph.

Diflubenzuron has an exceptionally low toxicity to fish. Rainbow trout, channel catfish, fathead minnows, and bluegills had relatively high 96-hour $LC_{50}$s, ranging from 240 mg/L for rainbow trout to 660 mg/L for bluegills (Julin and Sanders, 1978). EPA (1987) reports the acute toxicity of the fathead minnow as greater than 500 mg/L.

While diflubenzuron may have low toxicities to mammals, birds, insects, and fish, it is extremely toxic to crabs, shrimp, and other aquatic invertebrates (Uniroyal, undated). Diflubenzuron disrupts the development and reproduction of crustaceans and causes mortality by interfering with the development of a new exoskeleton during molting. Growing larvae are generally more susceptible than adults.

A recent study on acute toxicity of diflubenzuron to various life stages of the grass shrimp showed that larval and postlarval life stages were the most sensitive, with 96-hour mean $LC_{50}$s of 0.00144 and 0.00162 mg/L, respectively. Adult grass shrimp had a higher mean $LC_{50}$ of 6.985 mg/L (Wilson and Costlow, 1987).

No information is available on the toxicity of diflubenzuron to amphibians or reptiles.

***Methyl Parathion.*** The methyl parathion oral $LD_{50}$ values for rats and mice are 420 and 23 mg/kg, respectively (NIOSH, 1983; as cited in EPA, 1984). The oral $LD_{50}$ for dogs is 90 mg/kg (Hirschelmann and Bakemeier, 1975; as cited in EPA, 1984).

According to studies by the registrant, the encapsulated formulation of methyl parathion is less acutely toxic to mammals both orally and dermally than the liquid and emulsifiable concentrate formulations (Pennwalt, 1985). However, no long-term studies using the encapsulated formulation are available.

The oral $LD_{50}$s of methyl parathion for female and male mallards are 6.60 and 10.0 mg/kg, respectively (Hudson et al., 1984). The $LD_{50}$s for bobwhites and pheasants are 7.56 and 8.21 mg/kg, respectively (Hudson et al., 1984). For red-winged blackbirds the $LD_{50}$ is 10 mg/kg (Schafer, 1972; as cited in Smith, 1987), and it is 3.08 mg/kg for American kestrels (Rattner and Franson, 1984; as cited in Smith, 1987).

Methyl parathion has not been conclusively linked with direct reproductive impairment in laboratory studies, although some studies have noted significant depression in brain ChE activity. Field studies, however, have suggested that methyl parathion may affect avian reproductive success (EPA, 1986b).

Methyl parathion is highly toxic to bees and can cause substantial losses, particularly if the bees are exposed to direct treatment or to insecticide residues on crops and other blooming plants (Pennwalt, 1987; McLaren et al., 1987). Hybrids of Italian and African bees had a low $LD_{50}$ of 0.000061 mg/bee, although these hybrids were reported to be more sensitive than California bees (Biosis Previews, 1988).

As summarized in McLaren et al. (1987), microencapsulated methyl parathion is particularly hazardous to honey bees (*Apis mellifera* L.). The size of the spherical nylon microcapsules containing methyl parathion is similar to numerous pollen types. When microencapsulated

methyl parathion is sprayed over blooming plants, bees collect pollen contaminated with the microcapsules and store it in combs in their hives. Unlike liquid methyl parathion, the microencapsulated formulation has a long residual life, and when packed into the combs, the microcapsules are potentially hazardous for months after the application. Young bees and larvae are quite susceptible to microencapsulated methyl parathion, as observed in several studies reported in McLaren et al. (1987).

A comparative study of microencapsulated methyl parathion and the liquid emulsifiable concentrate showed significantly higher mortality to bees foraging for pollen on artificial flowers treated with the microencapsulated formulation. Although both the microencapsulated and emulsifiable concentrate treatments exhibited high mortality on day 1 of the experiment, bee mortality on subsequent days for the emulsifiable concentrate treatment was not significantly different from the untreated controls' death rate, while the microencapsulated treatment continued to show an elevated mortality rate (McLaren et al., 1987).

Yellow perch, bluegill, and largemouth bass are sensitive to methyl parathion. Their 96-hour $LC_{50}$s are 3.06, 4.38, and 5.22 mg/L, respectively (Mayer and Ellerseick, 1986).

As summarized in EPA (1984), methyl parathion exposure may be more toxic to freshwater invertebrates than it is to fish. The 96-hour $LC_{50}$s are 0.003 mg/L for the crayfish *Procambarus clarki* and 0.015 mg/L for the crayfish *Orconectes nais*. For the crustacean scud *Gammarus fasciatus*, the 96-hour $LC_{50}$ is 0.0038 mg/L. The 48-hour $LC_{50}$ for the daphnids *Daphnia magna* and *Simocephalus serrulatus* are 0.00014 and 0.00037 mg/L, respectively, while the larval stages of the damselfly and gnat have $LC_{50}$s of 0.033 and 0.0012 mg/L, respectively.

Marine crustaceans are also highly susceptible to methyl parathion toxicity. The 96-hour $LC_{50}$s for the hermit crab, mysid shrimp, sand shrimp, and grass shrimp range from 0.00077 to 0.007 mg/L (EPA, 1986b).

The 96-hour $LC_{50}$ for western chorus frog tadpoles is 3.70 mg/L (Mayer and Ellerseick 1986). The true frog (genus *Rana*, common name unknown) became excitable and hyperactive, with heavy foaming and mucus secretions, after exposure to methyl parathion. The 96-hour $LC_{50}$s for male and female frogs were noted at 8.0 and 11.5 mg/L, respectively (Mudgall and Patil, 1987).

### Nontarget Species Exposure Analysis

For terrestrial wildlife species, typical and extreme exposures were calculated. These doses are a result of exposure through several routes—dermal, oral via grooming, and oral via eating, and inhalation. In a typical dose, the exposure comes from contact with vegetation at a drift distance of 25 feet from a treated field and from ingestion of

contaminated diet items that constitute a percentage of an animal's daily food intake. In the extreme case, the animal is assumed to be directly sprayed and to consume only contaminated food. In the case of honey bees, the typical doses are from drift at 25 feet, and the extreme doses are the result of a direct spray.

For aquatic species, exposures were calculated assuming that various representative water bodies in the Cotton Belt were contaminated by insecticide drift, direct spray, or contaminated runoff. In ponds, drift was calculated using the AGDISP model, and runoff levels were estimated using the GLEAMS model. The GLEAMS model was also used to estimate exposure levels to aquatic species in streams or small rivers. Four water bodies—Neal's Creek in North Carolina, the Pearl River in Mississippi, Leon Creek in Texas, and Aravaipa Creek in Arizona—were selected to represent each principal region of the Cotton Belt in the GLEAMS calculations. In addition, exposures were estimated for aquatic species in five major rivers—the Tennessee River, the Flint River, the Sunflower River, the Red River, and the Gila River—that receive runoff from adjacent cotton-growing areas. The EXAMS model was used to predict runoff levels in the major rivers. The AGDISP, GLEAMS, and EXAMS models are described in detail in appendix B (section B8). Details of the terrestrial and aquatic species exposure analysis are found in section B6.

### Nontarget Species Risk Analysis

The criteria that EPA uses in ecological risk assessment (EPA, 1986e) were used as the basis for judging the risks to different representative species and the relative risks among the four insecticides. The EPA criteria call for comparison of the estimated environmental concentration (EEC) with the $LD_{50}$ for terrestrial species or the $LC_{50}$ for aquatic species for the most closely related species for which a toxicity level has been determined.

For evaluation of risks to terrestrial species, if the EEC is equal to or greater than or equal to the $LD_{50}$, EPA (1986e) deems it a significant, unacceptably high risk. If the EEC is greater than or equal to 1/5 the $LD_{50}$ but is less than the $LD_{50}$, EPA considers that level to result in a moderate risk that may be mitigated by appropriate restrictions. At EECs less than 1/5 the $LD_{50}$, EPA assumes there is a low or negligible acute risk to that species. In this risk assessment, an organism's total dose, rather than an EEC, is compared with the laboratory toxicity level because the dose comes from all exposure routes, not just feeding. This is summarized below.

| Dose | Risk to terrestial species |
|---|---|
| <1/5 $LD_{50}$ | Low risk |
| ≥1/5 $LD_{50}$ but less than $LD_{50}$ | Moderate risk (presumption of risk that may be mitigated) |
| ≥$LD_{50}$ | High risk |

To estimate the risks of adverse effects to aquatic species, the toxicity reference values determined in the hazard analysis were compared to the EECs estimated for each insecticide. The analysis looked at insecticide levels in representative water bodies that typically occur in the Cotton Belt, including on-site farm ponds, streams or small rivers, and large rivers. For evaluation of risks to aquatic species, if the EEC is greater than or equal to 1/2 the $LC_{50}$, EPA deems it a significant, unacceptably high risk. If the EEC is greater than or equal to 1/10 the $LC_{50}$ but is less than 1/2 the $LC_{50}$, EPA considers that level to result in a moderate risk that may be mitigated by appropriate restrictions. If the EEC is less than 1/10 the $LC_{50}$, EPA assumes there is a low or negligible risk to that species.

| EEC | Risk to aquatic species |
|---|---|
| <1/10 $LC_{50}$ | Low risk |
| ≥1/10 $LC_{50}$ but <1/2 $LC_{50}$ | Moderate risk (presumption of risk that may be mitigated) |
| ≥1/2 $LC_{50}$ | High acute |

## Risks to Nontarget Terrestrial Wildlife Species

Risks to terrestrial wildlife species are summarized in table 4-3.

*Malathion.* In the typical case, drift residues of malathion pose a low risk to terrestrial wildlife; none of the typical case dose estimates exceed the 1/5 $LD_{50}$ values for wildlife. In the extreme case, the insecticide poses a moderate risk to honey bees that are directly sprayed. Honey bees present in a cotton field during spraying operations are likely to be killed.

*Azinphos-methyl.* Drift residues of azinphos-methyl pose a low risk to terrestrial representative species. In the extreme case, however, a direct spray of azinphos-methyl poses a moderate risk to the eastern cottontail, desert cottontail, red fox, coyote, cotton mouse, deer mouse, and honey bee and a high risk to the eastern and western kingbirds, eastern garter snake, western diamondback rattlesnake, Fowler's toad, Rocky Mountain toad, and red-spotted toad.

**Table 4-3. Summary of Highest Risks to Nontarget Terrestrial Species From Insecticides**

| Species | Malathion | | Azinphos-methyl | | Diflubenzuron | | Methyl parathion | |
|---|---|---|---|---|---|---|---|---|
| | Typical | Extreme | Typical | Extreme | Typical | Extreme | Typical | Extreme |
| Birds | C | C | C | A | C | C | B | A |
| Mammals | C | C | C | B | C | C | C | A |
| Reptiles | C | C | C | A | C | C | B | A |
| Amphibians | C | C | C | A | C | C | B | A |
| Insect | C | B | C | B | C | C | B | A |
| Domestic animals | C | C | C | C | C | C | C | B |

Note: Risks are categorized as follows:

A = High risk—Dose is greater than or equal to $LD_{50}$ for terrestrial species.
B = Moderate risk—Dose is greater than or equal to 1/5 $LD_{50}$ but is less than $LD_{50}$ for terrestrial species.
C = Low risk—Dose is less than 1/5 $LD_{50}$ for terrestrial species.

***Diflubenzuron.*** In both the typical and extreme cases, diflubenzuron presents a low risk to terrestrial wildlife.

***Methyl Parathion.*** Drift residues of methyl parathion present a moderate risk to the eastern and western kingbirds, belted kingfisher, eastern garter snake, western diamondback rattlesnake, Fowler's toad, Rocky Mountain toad, red-spotted toad, and honey bee. A direct spray of the insecticide presents a moderate risk to the northern bobwhite, Gambel's quail, white-tailed deer, and mule deer. Direct spray also poses a moderate risk to two domestic animals, the cow and the chicken. Direct spray presents a high risk to the eastern and western kingbird, American kestrel, belted kingfisher, cotton mouse, deer mouse, eastern garter snake, western diamondback rattlesnake, Fowler's toad, Rocky Mountain toad, red-spotted toad, and honey bee.

### Risks to Nontarget Aquatic Species

Tables 4-4, 4-5, and 4-6 summarize the risks to fish and invertebrate aquatic species in ponds, streams, or rivers receiving drift, direct spray, or runoff concentrations of insecticide.

In the pond model, a 2-foot-deep pond 25 feet from a treated area was assumed to cover 1 acre in area. The pond was assumed to receive drift residues created by a crosswind with a speed of 10 miles per hour. In addition, runoff was assumed to drain into the pond from 30 acres of cotton field and from 3 acres of nonagricultural areas, such as access roads and buffer areas.

For streams and small rivers, the results of the GLEAMS analysis were input into a small river model to obtain water concentrations at the upstream limit of the aquatic habitat. For the purposes of runoff modeling on a watershed basis, it was assumed that the cotton acreage present in each county of concern was distributed evenly throughout the county. The total pesticide mass leaving each field was distributed throughout the stream volume for an average stream concentration. Streamflows were obtained from U.S. Geological Survey data.

In all rivers modeled with EXAMS, several conservative assumptions were inherent in the runoff calculations, including the following:

- The Tennessee River basin was treated over 3 consecutive days. The watersheds for the other river basins were assumed to be treated entirely at one time.

- The maximum frequency of treatment under each alternative was assumed for all cotton-producing acres in the entire basin.

- Treatment was followed by a 2-year storm (that is, a storm of a severity that is no more than 50 percent likely to occur each year).

Table 4-4. Summary of Highest Risks to Aquatic Species in Ponds

| Species | Malathion | | Azinphos-methyl | | Diflubenzuron | | Methyl parathion | |
|---|---|---|---|---|---|---|---|---|
| | Typical | Extreme | Typical | Extreme | Typical | Extreme | Typical | Extreme |
| Fish | A | A | A | A | C | C | C | C |
| Aquatic invertebrates | A | A | A | A | A | A | A | A |
| Amphibians | B | A | B | A | ND | ND | C | C |

Note: Risks are categorized as follows:

A = High risk—Estimated environmental concentration (EEC) is greater than or equal to ½ $LC_{50}$ or ½ $EC_{50}$ for aquatic species.
B = Moderate risk—EEC is greater than or equal to 1/10 $LC_{50}$ or 1/10 $EC_{50}$ but is less than ½ $LC_{50}$ or ½ $EC_{50}$ for aquatic species.
C = Low risk—EEC is less than 1/10 $LC_{50}$ or 1/10 $EC_{50}$ for aquatic species.
ND = No data.

**Table 4-5. Summary of Highest Risks to Aquatic Species in Streams or Small Rivers**

| Insecticide | Neal's Creek | | | Pearl River | | | Leon Creek | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fish | Invertebrate | Amphibian | Fish | Invertebrate | Amphibian | Fish | Invertebrate | Amphibian |
| **Typical:** | | | | | | | | | |
| Malathion | C | A | C | B | A | C | C | A | C |
| Azinphos-methyl | B | A | C | A | A | C | B | A | C |
| Diflubenzuron | C | C | ND | C | C | ND | C | C | ND |
| Methyl parathion | C | A | C | C | A | C | C | A | C |
| **Extreme:** | | | | | | | | | |
| Malathion | B | A | C | B | A | C | C | A | C |
| Azinphos-methyl | A | A | C | A | A | C | B | A | C |
| Diflubenzuron | C | A | ND | C | C | ND | C | C | ND |
| Methyl parathion | C | A | C | C | A | C | C | A | C |

| Insecticide | Aravaipa Creek | | |
|---|---|---|---|
| | Fish | Invertebrate | Amphibian |
| **Typical:** | | | |
| Malathion | C | A | C |
| Azinphos-methyl | B | A | C |
| Diflubenzuron | C | C | ND |
| Methyl parathion | C | A | C |
| **Extreme:** | | | |
| Malathion | B | A | C |
| Azinphos-methyl | A | A | C |
| Diflubenzuron | C | B | ND |
| Methyl parathion | C | A | C |

Note: Risks are categorized as follows:

A = High risk—Estimated environmental concentration (EEC) is greater than or equal to ½ $LC_{50}$ or ½ $EC_{50}$.
B = Moderate risk—EEC is greater than or equal to 1/10 $LC_{50}$ or 1/10 $EC_{50}$ but is less than ½ $LC_{50}$ or ½ $EC_{50}$.
C = Low risk—EEC is less than 1/10 $LC_{50}$ or 1/10 $EC_{50}$.
ND = No data.

**Table 4-6. Summary of Highest Risks to Aquatic Species in Large Rivers**

| Insecticide | Tennessee River | | | Flint River | | | Sunflower River | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fish | Invertebrate | Amphibian | Fish | Invertebrate | Amphibian | Fish | Invertebrate | Amphibian |
| **Eradication:** | | | | | | | | | |
| Malathion | C | B | C | C | A | C | A | A | B |
| Azinphos-methyl | C | A | C | B | A | C | A | A | C |
| Diflubenzuron | C | C | ND | C | C | ND | C | A | ND |
| Methyl parathion | C | B | C | C | A | C | C | A | C |
| **Suppression:** | | | | | | | | | |
| Malathion | C | A | C | C | A | C | A | A | B |
| Azinphos-methyl | C | A | C | B | A | C | A | A | C |
| Diflubenzuron | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Methyl parathion | C | A | C | C | A | C | C | A | C |

| Insecticide | Red River | | | Gila River | | |
|---|---|---|---|---|---|---|
| | Fish | Invertebrate | Amphibian | Fish | Invertebrate | Amphibian |
| **Eradication:** | | | | | | |
| Malathion | A | A | A | B | A | C |
| Azinphos-methyl | A | A | B | A | A | C |
| Diflubenzuron | C | A | ND | C | A | ND |
| Methyl parathion | C | A | C | C | A | C |
| **Suppression:** | | | | | | |
| Malathion | A | A | A | B | A | C |
| Azinphos-methyl | A | A | B | A | A | C |
| Diflubenzuron | ND | ND | ND | ND | ND | ND |
| Methyl parathion | C | A | C | C | A | C |

Note: Risks are categorized as follows:

A = High risk—Estimated environmental concentration (EEC) is greater than or equal to ½ $LC_{50}$ or ½ $EC_{50}$.
B = Moderate risk—EEC is greater than or equal to 1/10 $LC_{50}$ or 1/10 $EC_{50}$ but is less than ½ $LC_{50}$ or ½ $EC_{50}$.
C = Low risk—EEC is less than 1/10 $LC_{50}$ or 1/10 $EC_{50}$.
ND = No data.

- The storm occurred over the entire basin.

- Dams, levees, strips of vegetation, and other obstructions to drainage were not accounted for. In actuality, the existence of these obstructions decreases the amount of insecticide-laden silt that reaches the lower stretches of a river. (See appendix B, section B8, for a detailed discussion of the runoff modeling.) Therefore, in a conservative scenario, there are likely to be temporary insecticide concentrations in rivers that receive runoff from treated fields that are hazardous to aquatic species. In most cases, serious adverse effects to entire populations of species in rivers are not expected, although some individual organisms are likely to die.

***Malathion.*** In ponds, average runoff concentrations of malathion (typical case) present a moderate risk to green sunfish, largemouth bass, yellow perch, Fowler's toad tadpoles, and western chorus frog tadpoles and a high risk to bluegills, daphnia, scuds, grass shrimp, and stoneflies. Extreme runoff concentrations of malathion (extreme case) in ponds present a moderate risk to Fowler's toad tadpoles and a high risk to bluegills, green sunfish, largemouth bass, yellow perch, daphnia, scuds, grass shrimp, stoneflies, and western chorus frog tadpoles.

In Neal's Creek, malathion concentrations produced on a watershed basis (typical case) present a high risk to aquatic invertebrates, such as daphnia, scuds, and stoneflies. A "plug" concentration of malathion (extreme case) presents a moderate risk to bluegills and a high risk to daphnia, scuds, and stoneflies. Similarly, typical case concentrations of malathion in the Pearl River present a moderate risk to bluegills and a high risk to daphnia, scuds, and stoneflies. Extreme case concentrations of malathion present a moderate risk to bluegills and a high risk to daphnia, scuds, and stoneflies. In Leon Creek, both typical and extreme concentrations of malathion present high risks to daphnia, scuds, and stoneflies. In Aravaipa Creek, both the typical and extreme malathion levels present high risks to daphnia, scuds, and stoneflies. The extreme concentration of malathion in Aravaipa Creek also presents a moderate risk to bluegills and grass shrimp.

According to the EXAMS data, the concentration of malathion in the Tennessee River resulting from an eradication program presents a moderate risk to daphnia, scuds, and stoneflies. The concentration of malathion in the Tennessee River resulting from a suppression program presents a moderate risk to daphnia and stoneflies and a high risk to scuds. In the Flint River, both the eradication and suppression concentrations of malathion present high risks to daphnia, scuds, and stoneflies. In the Sunflower River, concentrations resulting from an eradication program present moderate risks to green sunfish, largemouth bass, yellow perch, and western chorus frog tadpoles and high risks to bluegills, daphnia, scuds, grass shrimp, and stoneflies. Suppression program concentrations of malathion in the Sunflower River present moderate risks to green sunfish, yellow perch, and

western chorus frog tadpoles and high risks to bluegills, daphnia, scuds, grass shrimp, and stoneflies. In the Red River, both the eradication and suppression concentrations of malathion present moderate risks to largemouth bass, yellow perch, and Fowler's toad tadpoles and high risks to bluegills, green sunfish, daphnia, scuds, grass shrimp, stoneflies, and western chorus frog tadpoles. In the Gila River, concentrations of malathion resulting from an eradication program present moderate risks to bluegills and grass shrimp and high risks to daphnia and stoneflies. Suppression concentrations of malathion in the Gila River present a moderate risk to bluegills and a high risk to daphnia, scuds, and stoneflies.

***Azinphos-methyl.*** Typical runoff concentrations of azinphos-methyl in ponds present a moderate risk to green sunfish, crayfish, and Fowler's toad tadpoles and a high risk to bluegills, largemouth bass, yellow perch, aquatic sowbugs, scuds, and stoneflies. Extreme runoff concentrations of azinphos-methyl in ponds present a moderate risk to fathead minnows and a high risk to bluegills, green sunfish, largemouth bass, yellow perch, aquatic sowbugs, scuds, crayfish, stoneflies, and western chorus frog tadpoles.

Typical case concentrations of azinphos-methyl in Neal's Creek present moderate risks to bluegills, yellow perch, and stoneflies, and a high risk to scuds. The extreme concentration of azinphos-methyl presents moderate risks to bluegills and largemouth bass and high risks to yellow perch, scuds, and stoneflies. In the Pearl River, both the typical and extreme azinphos-methyl levels pose a moderate risk to bluegills and largemouth bass and high risks to yellow perch, scuds, and stoneflies. In Leon Creek, both the typical and extreme concentrations of azinphos-methyl present moderate risks to bluegills, largemouth bass, yellow perch, and stoneflies and a high risk to scuds. In Aravaipa Creek, the typical and extreme azinphos-methyl levels present moderate risks to bluegills and largemouth bass and high risks to scuds and stoneflies. In addition, azinphos-methyl in Aravaipa Creek presents a moderate risk to yellow perch in the typical case and a high risk to this species in the extreme case.

Based on EXAMS data, azinphos-methyl levels in the Tennessee River resulting from both the eradication and suppression programs present a high risk to scuds. In the Flint River, eradication concentrations of azinphos-methyl present a moderate risk to bluegills, yellow perch, and stoneflies and a high risk to scuds. Suppression concentrations of azinphos-methyl in the Flint River present a moderate risk to yellow perch and stoneflies and a high risk to scuds. In the Sunflower River, concentrations of azinphos-methyl resulting from both eradication and suppression programs present moderate risks to green sunfish, aquatic sowbugs, and crayfish and high risks to bluegills, largemouth bass, yellow perch, scuds, and stoneflies. In the Red River, azinphos-methyl from both eradication and suppression programs presents moderate risks to fathead minnows, crayfish, and Fowler's toad tadpoles and high risks to bluegills, largemouth bass, yellow perch, aquatic sowbugs,

scuds, and stoneflies. Also, Red River concentrations of azinphos-methyl present a moderate risk to green sunfish during an eradication program and a high risk to this species in a suppression program. In the Gila River, azinphos-methyl from an eradication program presents moderate risks to aquatic sowbugs and high risks to bluegills, largemouth bass, yellow perch, scuds, and stoneflies. In a suppression program, azinphos-methyl in the Gila River presents moderate risks to bluegills and largemouth bass and high risks to yellow perch, scuds, and stoneflies.

***Diflubenzuron.*** Because diflubenzuron is not used for suppression, no suppression concentrations were estimated with EXAMS. In ponds, both the typical and extreme runoff concentrations of diflubenzuron present a moderate risk to scuds and a high risk to daphnia.

A "plug" concentration of diflubenzuron (extreme case) presents a moderate risk to daphnia in Aravaipa Creek and a high risk to this species in Neal's Creek. Neither the typical nor the extreme case concentrations of diflubenzuron present unacceptable risks to any aquatic species in the Pearl River or Leon Creek.

In the Sunflower River, concentrations of diflubenzuron from an eradication program present a moderate risk to scuds and a high risk to daphnia. Diflubenzuron presents a high risk to daphnia and scuds in the Red River and a high risk to daphnia in the Gila River. Diflubenzuron also presents a moderate risk to scuds in the Gila River.

***Methyl Parathion.*** Typical runoff concentrations of methyl parathion in ponds present a moderate risk to damselflies and a high risk to daphnia (*Daphnia magna* and *Simocephalus serrulatus*) and crayfish. Extreme runoff concentrations of methyl parathion in ponds present a high risk to daphnia (*D. magna* and *S. serrulatus*), damselflies, and crayfish.

Typical case concentrations of methyl parathion in Neal's Creek present a moderate risk to crayfish and high risks to daphnia (*D. magna* and *S. serrulatus*). Extreme concentrations of methyl parathion in Neal's Creek present high risks to crayfish and the two daphnia species. In the Pearl River, both the typical and extreme case concentrations present a moderate risk to crayfish and a high risk to *D. magna* and *S. serrulatus*. In Leon Creek, the typical and extreme concentrations present a moderate risk to *D. magna* and a high risk to *S. serrulatus*. In Aravaipa Creek, the typical case concentration of methyl parathion presents a moderate risk to crayfish and a high risk to *D. magna* and *S. serrulatus*, while the extreme case concentration presents a high risk to crayfish and the two daphnia species.

Concentrations of methyl parathion in the Tennessee River resulting from an eradication program present a moderate risk to *D. magna* and *S. serrulatus*. In a suppression program, methyl parathion in the

Tennessee River presents a moderate risk to *S. serrulatus* and a high risk to *D. magna*. In the Flint River, both the eradication and suppression programs present high risks to *D. magna* and *S. serrulatus*. In the Sunflower River, concentrations of methyl parathion from an eradication program present a moderate risk to crayfish and a high risk to *D. magna* and *S. serrulatus*, while a suppression program presents a moderate risk to damselflies and a high risk to crayfish, *D. magna*, and *S. serrulatus*. In the Red River, methyl parathion from either an eradication program or a suppression program presents a high risk to crayfish, *D. magna*, and S. serrulatus. Similarly, *D. magna* and *S. serrulatus* in the Gila River face high risks during eradication or suppression programs.

## Chronic Risks to Nontarget Wildlife Species

Evaluation of long-term risks to wildlife and aquatic species requires comparison of chronic toxicity values to doses (for terrestrial species) or EECs (for aquatic species). There is a considerable amount of uncertainty in determining appropriate toxicity values because the data base for chronic effects to nonmammalian species consists largely of field studies in which conditions may vary widely, both within the same study and among several studies. An overview of potential chronic effects to nontarget species from typical exposures is presented in this section. All the studies mentioned here are discussed in appendix B.

***Malathion.*** Typical doses calculated for rabbits, mice, red foxes, and coyotes approach or surpass the level at which effects were observed in long-term studies in laboratory animals. Reversible ChE inhibition might be observed in some members of these species. Chronic toxicity to nonmammalian species can be assessed with the use of field studies. The maximum application rate for malathion is 1.17 lb/acre in a boll weevil control program. Several field studies have indicated that no significant adverse effects on birds and mammals were noted when malathion was applied at rates of 0.5 to 1 lb/acre, except for slightly depressed ChE levels in avian species. Aquatic species in two farm ponds showed no mortality after repeated malathion applications at a rate of 1 lb/acre. However, in another study, the application of 0.5 lb/acre severely affected the population of invertebrate amphipods.

***Azinphos-methyl.*** A comparison of the lowest effect levels (LELs) observed in laboratory animals to typical doses to mammalian wildlife demonstrates that several species, including rabbits and mice, are likely to show effects from chronic exposures, particularly reversible ChE inhibition. The application rate for azinphos-methyl is 0.25 lb/acre in a boll weevil control program. Field studies in which it was applied at rates of up to 5 lb a.i./acre did not reveal any adverse effects to birds or animals. Azinphos-methyl has a high potential for fatal toxicity to aquatic species and has demonstrated the capacity to significantly reduce populations of bass and sunfish at an application rate of 0.25 lb/acre. Populations of zooplankton may be substantially reduced but will quickly return to normal levels.

*Diflubenzuron.* All typical doses to representative wildlife mammalian species are less than the lowest level at which adverse effects were observed in laboratory animals. The diflubenzuron application rate is 0.125 lb/acre in a boll weevil control program. Diflubenzuron applications of up to 0.25 lb/acre showed no adverse effects on small mammals in a boreal forest. No adverse effects on avian species or honey bees were observed in several field studies that used application rates of up to 0.0783 lb/acre. Diflubenzuron has a low toxicity to fish. However, populations of aquatic invertebrates, such as grass shrimp, water fleas, and mayflies, may be temporarily decreased, but they generally should recover within a reasonable period of time.

*Methyl Parathion.* All typical wildlife mammalian doses exceed the lowest level at which adverse effects were observed in laboratory animals. This may result in mild to moderate reversible ChE inhibition in exposed mammals. Although methyl parathion has a high acute toxicity, no field studies were available for comparison of the application rate proposed for use in a boll weevil control program with those that have caused adverse effects on overall health or population levels of mammalian, avian, or aquatic species. Temporary effects on zooplankton levels have been demonstrated, as well as effects on respiration in freshwater mussels and ChE inhibition in fish.

### Potential Impacts of Chemical Controls—Effects on Cotton Insects

In the absence of chemical treatments, cotton insect pests other than the boll weevil are sometimes kept below economically damaging levels by predators and parasites. These beneficial predators and parasites are in dynamic equilibrium with their pest prey or hosts. That is, when the pest population increases, the populations of beneficial insects increase and reduce the pest populations (Ables et al., 1978). While environmental conditions in some years may favor the growth of some pest species, biological controls can reassert their controlling influence and pest populations can again stabilize over time.

When broad spectrum or nonselective chemicals are applied to control boll weevils, the toxic effects of the chemical may reduce or eliminate both beneficial insect populations and nontarget pests. If the nontarget pest that is controlled by affected beneficial insects is unaffected by the chemical treatment, eliminating the beneficial insects may result in the nontarget pest population growing to damaging levels. Three chemicals—malathion, azinphos-methyl, and methyl parathion—proposed for foliar application in the National Boll Weevil Cooperative Control Program have been shown to be toxic to beneficial insect populations. These three chemicals are not effective in controlling some common secondary pests, including the tobacco budworm and the beet armyworm, on which beneficial insects prey. Thus, repeated application of these chemicals may result in the elimination of the beneficial insects and contribute to the growth of these secondary pest populations.

Recent efforts to manage insect pests have focused on conserving beneficial insect species whenever possible. The growth of beneficial

insects can be aided by using insecticides that affect only a limited number of beneficial species and by proper timing of broad-spectrum chemical applications. Using chemicals that have a more limited toxic effect reduces the impacts on beneficial species and lessens the potential for increased growth of the nontarget pest population. Chemical applications for target pests may also be timed to avoid effects on beneficial species during periods when beneficial control is most influential on nontarget pest populations. Spring treatments for boll weevil control are expected to have the greatest detrimental impact on the ability of beneficial insect populations to control secondary pests.

Repeated long-term application of broad-spectrum insecticides may also contribute to the development of resistance in both target and nontarget pest species. Since 1947, resistance to one or more insecticides has been confirmed in at least 21 species of cotton insects and mites (table 4-7). Some cotton pests, such as *Heliothis virescens,* are resistant to most major classes of insecticides in at least part of their range. In these resistant areas, beneficial insects may be the only control available to limit the size of this pest population. Elimination of beneficial insects in this instance would result in uncontrollable outbreaks of the pest (Knipling, 1979).

The following section examines the potential impact of chemical treatments applied for boll weevil control on nontarget cotton insect populations. Pest species that are effectively controlled by the particular chemical, resistant pest species, and susceptible beneficial species are identified.

### Effects of Chemical Controls

***Malathion.*** Malathion has been proven effective and is approved for use at program application rates in the control of grasshoppers (*Schistocerca* sp., *Trimerotropis* sp., and *Melanoplus* sp.); cotton fleahoppers (*Pseudatomoscelis seriatus* (Reuter)); lygus bugs, including the tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)); and thrips (*Frankliniella* sp., *Thrips* sp., and *Sericothrips* sp.). Other cotton pests that have demonstrated toxic effects include the cotton leafworm (*Alabama argillacea* (Hübner)) and the garden webworm (*Achyra rantalis* (Guenée)).

Malathion also causes varying but persistent degrees of toxicity to many beneficial insects, including lacewings, lady beetles, and parasitic wasps (Dobroski and Lambert, 1984). In addition, insects of the orders Homoptera (cicadas and fleahoppers), Hemiptera (damsel bugs and minute pirate bugs), and Hymenoptera (bees, wasps, and ants) are also susceptible to malathion treatments (Hill et al., 1971; Doane and Schafer, 1971; Martinez and Pienkowski, 1983).

Malathion is not effective in the control of numerous cotton pests, including the tobacco budworm (*Heliothis virescens* (Fabricius)), the cotton bollworm (*Heliothis zea* (Boddie)), the beet armyworm (*Spodoptera exigua* (Hübner)), and lygus bugs (*Lygus* sp.). Predators of these pests

**Table 4-7. Common Cotton Insect Pests and Chemical Resistances**

| Insect | Resistance[a] |
|---|---|
| Beet armyworm (*Spodoptera exigua* (Hübner)) | Organochlorides, methyl parathion |
| Boll weevil (*Anthonomus grandis* (Boheman)) | Organochlorines |
| Bollworm (*Heliothis zea* (Boddie)) | DDT, endrin, carbaryl, methyl parathion, TDE toxaphene + DDT, strobane + DDT, methomyl |
| Cabbage looper (*Trichoplusia ni* (Hübner)) | DDT, organochlorines, endrin, toxaphine, organophosphates |
| Cotton aphid (*Aphis gossypii* (Glover)) | Benzene hexachloride, organophosphates |
| Cotton fleahopper (*Pseudatomoscelis seriatus* (Reuter)) | Organochlorines, organophosphates |
| Cotton leaf perforator (*Bucculatrix thurberiella* (Busck)) | Organochlorines, organophosphates, DDT |
| Cotton leafworm (*Alabama argillacea* (Hübner)) | Organochlorines |
| Lygus bugs (*Lygus hesperus* (Knight), *Neurocolpus nubilus* (Say), *Chlamydatus associatus* (Uhler), *Adelphocoris rapidus* (Say), *Adelphocoris superbus* (Uhler), *Lygus lineolaris* (Palisot de Beauvios)) | Trichlorfon, moncrotophos, DDT, malathion |
| Pink bollworm (*Pectinophera gossypiella* (Saunders)) | DDT |
| Saltmarsh caterpillar (*Estigmene acrea* (Drury)) | Toxaphene, DDT, endrin |
| Seedcorn maggot (*Hylemya platura* (Meigen)) | Toxaphene, DDT, endrin |
| Spider mites (*Tetranychus* spp.) | Organophosphates, dicofol |
| Stink bugs (Various species) | Organochlorines |
| Thrips (*Frankliniella exigua* (Hood), *Frankliniella fusca* (Hinds) *Frankliniella gossypiana* (Hood), *Frankliniella occidentalis* (Pergande), *Frankliniella tritici* (Fitch), *Thrips tabaci* (Lindeman), *Sericothrips variablis* (Beach)) | Dieldrin, endrin, toxaphene, organochlorines |
| Tobacco budworm (*Heliothis virescens* (Fabricius)) | DDT, endrin, strobane + DDT, TDE, toxaphene + DDT, methomyl, organophosphorus compounds, carbaryl, pyrethroids |
| White flies (*Trialeurodes abutilonea* (Haldeman), *Trialeurodes vaporarium* (Westwood), *Bemisia tabaci* (Gennaduis)) | Methyl parathion |

[a] Resistance demonstrated to compound in all or part of range.

Sources: Adapted from NRC, 1981; USDA, 1983.

that are affected by malathion applications include green lacewings (*Chrysopa* spp.), brown lacewings (*Hemerobius* spp.), lady beetles (*Coccinella* and *Hippodamia* spp.), and big-eyed bugs (*Geocoris* spp.). A significant factor in the relative susceptibility of insects to malathion is that comparatively less of the insecticide is needed to kill the beneficial insects than is needed to kill the pest species (Dobroski and Lambert, 1984).

Because of the relatively short-term residual effects of malathion, reductions in beneficial insect populations are only temporary, and fairly rapid reestablishment of these beneficial insects by immigration from adjacent fields may be expected (Manser and Bennet, 1963). The timing of the malathion treatments influences the ability of the beneficial population to reassert control over the pest species. Spring (pinhead-square) treatments often do not allow sufficient time for recovery of the beneficial species to adequately control *Heliothis* spp. populations (Reynolds et al., 1982; NRC, 1981). The loss of beneficial insects from spring treatments can contribute to large pest outbreaks brought on by favorable environmental conditions. Lloyd (1988) examined an unusual beet armyworm problem in Alabama and concluded that the outbreak was strongly correlated with an early season drought across the region. Counties in Alabama that did not treat for boll weevils in the spring experienced similar outbreaks.

Some species of lygus bugs have demonstrated resistance to malathion. Other cotton pests that have demonstrated resistance to organophosphate insecticides as a class in at least part of their range include the tobacco budworm, the cabbage looper, the cotton fleahopper, the cotton leaf perforator, and some species of spider mites.

***Azinphos-methyl.*** Azinphos-methyl has been proven effective and is approved for use at program application rates for controlling the cotton leafworm (*Alabama argillacea* (Hübner)), the cotton fleahopper (*Pseudatomoscelis seriatus* (Reuter)), lygus bugs (*Lygus* spp.), and thrips (*Frankliniella* spp., *Thrips* spp. and *Sericothrips* spp.). Effective control may be achieved at higher application rates for the tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)) and the pink bollworm (*Pectinophora gossypiella* (Saunders)). Although approved for use against the *Heliothis* spp. complex, some studies have shown that adequate control cannot be achieved with azinphos-methyl (Lambert, 1985). The cotton aphid (*Aphis gossypii* (Glover) has also shown toxic effects to azinphos-methyl.

Azinphos-methyl is also toxic to a number of beneficial insects, including lady beetles (*Coleomegilla* spp. and *Hippodamia* spp.), the minute plant bug (*Orius insidiosus* (Say)), big-eyed bugs (*Geocoris puntipes* (Say)), damsel bugs (*Nabis* spp.), and green lacewings (*Chrysopa* spp.) (Lambert, 1985). Azinphos-methyl appears to be more selective for predators than for cotton insect pests. That is, less of the insecticide is required to kill the predator than its prey. However, azinphos-methyl

is not as selective as malathion for predators (Martinez and Pienkowski, 1983; Anderson et al., 1974).

Azinphos-methyl has relatively short-term residual effects, and fairly rapid reestablishment of these beneficial insects has been shown after a single treatment. However, multiple applications of azinphos-methyl reduce beneficial populations to the point that the populations cannot recover in a single season (Laster and Brazzel, 1968). The timing of the azinphos-methyl treatments may influence the ability of the beneficial insects to recover after treatments. Spring (pinhead-square) treatments are expected to have the greatest impact on these beneficial species.

No species of cotton insect pest has demonstrated specific resistance to azinphos-methyl, although species that have demonstrated resistance to organophosphates as a class in at least part of their range include the tobacco budworm, the cabbage looper, the cotton fleahopper, the cotton leaf perforator, and some species of spider mites.

***Diflubenzuron.*** Diflubenzuron has been proven effective and has been approved for use on cotton for boll weevil control. Diflubenzuron is also registered for control of leaf perforator, fall armyworm, and beet armyworm. Evidence concerning effectiveness against other cotton insect pests is lacking. Diflubenzuron is nontoxic to the tobacco budworm (*Heliothis virescens* (Fabricius)) and the cotton bollworm (*Heliothis zea* (Boddie)) (EPA, 1979). Field studies of diflubenzuron have concluded that the chemical does not affect beneficial insects or disturb the relative abundance of the predators sampled (Metcalf, 1980; Harding, 1980; Keever et al., 1977; EPA, 1979). No cotton insect pests have demonstrated resistance to diflubenzuron.

***Methyl Parathion.*** Methyl parathion has been proven effective and is approved for use at program application rates in the control of cotton fleahoppers (*Pseudatomoscelis seriatus* (Reuter)), plant bugs (including *Lygus* spp.), and thrips (*Frankliniella* spp., *Thrips* spp., and *Sericothrips* spp.). At higher application rates than that proposed, methyl parathion has demonstrated some effectiveness in the control of the tobacco budworm (*Heliothis virescens* (Fabricius)) and the cotton bollworm (*Heliothis zea* (Boddie)). Other cotton pests that have demonstrated toxic effects to methyl parathion include the beet armyworm, the cotton aphid, the cotton leafworm, the fall armyworm, the garden webworm, the saltmarsh caterpillar, spider mites, stink bugs, and the yellow-striped armyworm.

Methyl parathion is also toxic to a number of beneficial insects, including green lacewings (*Chrysopa* spp. and *Hippodamia* spp.), collops beetles (*Collops* spp.), big-eyed bugs (*Geocoris* spp.), damsel bugs (*Nabis* spp.), and parasitic Hymenoptera (Lingren and Ridgway, 1967; Pennwalt Corporation, 1987).

Because of the relatively short-term residual effects of methyl parathion, reduction in beneficial insect populations may be expected to be

temporary and reestablishment of the population fairly rapid after a single application. Repeated applications may reduce the populations to the point that recovery in a single season is impossible. Spring (pinhead-square) treatments are expected to have the greatest impact on these beneficial species.

Cotton pest species that have demonstrated specific resistance to methyl parathion in at least part of their range include the beet armyworm, the cotton bollworm, and numerous species of white flies. Other cotton pests that have demonstrated at least some resistance to the organophosphate class of insecticides in at least part of their range include the tobacco budworm, the cabbage looper, the cotton leaf perforator, and some species of spider mites.

## Potential Impacts of Alternatives

### No Action

The no action alternative involves a continuation of current grower practices with no Federal involvement. This alternative presents an unknown impact on nontarget animal species because it is not known what control measures growers may choose in the future.

Fewer growers currently use cultural control methods than would be expected under a cooperative control program. For this reason, the impacts associated with the use of cultural control methods could be less than anticipated under the other alternatives. Site-specific impacts, such as habitat disturbance from noise, dust, and vibration; injury or fatalities caused by heavy equipment; habitat elimination resulting from the removal of host plant material; and increased turbidity of surface waters from erosion might still occur on fields where growers use these methods. Growers currently do not use mass trapping or sterile insects to control the boll weevil.

It is also unknown what chemicals individual growers may choose to use, in what quantity the chemicals are applied, and what operational and mitigation procedures are used to protect sensitive wildlife populations. Because these factors are unknown, this alternative could present higher toxic effects on nontarget species than either the eradication or suppression alternative.

Some chemicals used by growers may be more or less toxic than those proposed for use in the National Boll Weevil Cooperative Control Program. If the chemical chosen is more toxic, wildlife populations in cotton-producing areas could be reduced as a result of direct exposure or habitat contamination. Increased chemical toxicity can also affect reproductive success and the overall health of individual animals.

Growers may also apply insecticides either more or less frequently than the schedule proposed in the boll weevil control program. Increased frequency of application may lead to increased accumulation of insecticides in an animal's habitat, resulting in intensified toxic effects.

Increased toxicity from frequent applications may also lead to increased concentrations of insecticides in surface water from runoff and drift. Higher concentrations of insecticides in surface water increase the potential risk to aquatic species.

### Beltwide Eradication Program

Under the eradication alternative (both full and limited Federal involvement), boll weevil control methods may have a significant impact on some terrestrial and aquatic species. Cultural control methods may result in site-specific impacts, such as habitat disturbance from noise, dust, and vibration and injury or fatalities from heavy equipment. However, the activities that result in these impacts are temporary and limited to only a few days in the growing season. Cultural control methods that involve elimination of host plant material may increase turbidity of surface waters from erosion and lead to greater runoff of agricultural chemicals into nearby surface water. However, impacts associated with the use of cultural controls are not expected to exceed the impacts associated with normal agricultural practices. Also, the use of mechanical control and sterile boll weevils would have no significant impact on nontarget species.

The use of chemical controls may have a significant impact on terrestrial or aquatic species. The degree of impact would depend on the chemical selected for treatment. For example, the use of malathion will not result in significant impacts on most terrestrial species. However, malathion may affect populations of foraging bees and other beneficial insects that are directly sprayed, as well as aquatic species that are exposed to direct spray, spray drift, or runoff.

The use of azinphos-methyl poses risks for adverse effects to several avian, mammalian, insect, fish, and aquatic invertebrate species exposed to direct spray, spray drift, or runoff from treated fields. No significant impact on terrestrial species is expected from the use of diflubenzuron. Some invertebrate aquatic species may be significantly impacted by the use of diflubenzuron under extreme exposure conditions.

The use of methyl parathion poses risks similar to those described for terrestrial species from azinphos-methyl. Methyl parathion also poses significant risk to aquatic invertebrates if surface water is exposed to direct spray or spray drift or receives substantial runoff from treated fields.

Risks to bees from the chemicals may be mitigated by notifying apiarists of treatment schedules. Risks to other beneficial species may be mitigated by modifying treatment schedules. Impacts of the chemicals on aquatic species may be mitigated by avoiding direct spray of surface water and avoiding spraying when weather conditions are likely to increase runoff or spray drift. Impacts on terrestrial species may be minimized by avoiding direct spraying of adjacent habitats and

by avoiding spraying when conditions exist that may exacerbate spray drift.

### Beltwide Suppression Program

Under the suppression alternative (both full and limited Federal involvement), boll weevil control methods may have a significant impact on some terrestrial and aquatic species. The impact of the use of cultural controls is identical to impacts under the eradication alternative. Mechanical control and the release of sterile insects would not be used under this alternative.

While the affected species may vary slightly under the suppression alternative, the impacts of the use of chemical controls (except for diflubenzuron, which is not used for suppression) are not significantly different from those described under the eradication alternative. However, because the suppression program is expected to continue over an indefinite number of years, there could be the potential for somewhat higher risk over the long term. Also, in a program with limited Federal involvement, it would be difficult to ensure that growers were using only the program chemicals that have been analyzed. Mitigation measures are the same as those for an eradication program.

## Human Health and Safety

This section presents the human health risk associated with each nonchemical and chemical boll weevil control method, as well as the potential risks associated with the three program alternatives for boll weevil control. Human health risks from mechanical techniques used in cultural boll weevil control methods are limited to mechanical accidents and minor upper respiratory irritation. Human health risks associated with chemical control methods are greater for workers than for the general public. A relative ranking of overall risk potential from the chemicals to workers and the general public is, from most significant to least significant, methyl parathion, azinphos-methyl, malathion, and diflubenzuron.

### Potential Effects of Nonchemical Control Methods

Nonchemical methods of boll weevil control include cultural, mechanical, and sterile insect techniques.

### Cultural Methods

As described previously, cultural methods of boll weevil control include short-season techniques, postharvest stalk destruction, trap cropping, and crop rotation. Of these, only postharvest stalk destruction could be expected to pose risks to human health, but it is a necessary preplanting agricultural practice.

Tractors, mowers, discs, and plows are used for postharvest stalk destruction. The equipment operators and others working near the equipment may receive injuries from accidental contact with the equipment or its attachments (blades, mowers, and plows). Injuries also can result from working with machinery that tends to be slippery or oily during operation or repair. In addition, during dry seasons, use of machinery produces considerable dust and other particulate matter, which may produce upper respiratory irritation and, in the case of sensitive individuals, induce an allergic response.

### Mechanical Methods

Mechanical control by mass trapping is not expected to present a risk of human health effects. The pheromone lure used in the traps is nontoxic, and workers avoid skin contact with insecticide strips.

## Potential Effects of Chemical Control Methods

The potential human health effects from malathion, azinphos-methyl, diflubenzuron, methyl parathion, and xylene (an inert ingredient in the Penncap M® formulation of methyl parathion) for boll weevil eradication and suppression in cotton-producing States are evaluated in the risk assessment. Although propoxur and chlorpyrifos may also be used in traps for boll weevil eradication or suppression programs, the potential for exposure of these insecticides to workers and the public is not considered significant. Therefore, these chemicals were not included in the risk analysis.

### Human Risk Assessment Structure

The risk assessment consisted of three steps—a hazard analysis, an exposure analysis, and a risk analysis (fig. 4-2 illustrates the components of this process).

A ***hazard*** presented by a chemical pesticide results from its inherent toxicity or poisonous qualities. Hazardous effects could be brief and reversible, or as extreme as death. All chemicals can cause harm at some level, even such commonly consumed items as aspirin, table salt, and sugar.

***Exposure*** is the amount of pesticide in an individual's immediate surroundings (in the air, on the skin, or in drinking water or food). The amount that enters the body—that is ingested, inhaled, or that penetrates the skin during a specified time period—is the ***dose***. A dose is usually expressed in milligrams of chemical per kilogram of body weight (mg/kg). ***Risk*** from a chemical pesticide is the expectation that under a specified set of circumstances leading to a given exposure, an individual may experience any of the toxic effects described as the hazard of the chemical. Risk is the possibility of experiencing toxic effects attributable to an exposure to one of the alternative pesticides.

Figure 4-2. Components of the Risk Assessment Process

### Hazard Analysis

- Identify what kinds of health effects have been observed in laboratory animals and at what levels of exposure
- Identify any health effects that have been observed in humans
- Determine median lethal dose ($LD_{50}$) for acute effects from laboratory rat study
- Determine lowest no-observed-effect levels (NOELs), if possible, for general chronic toxic effects, reproductive effects, and birth defects
- Determine whether the pesticide potentially causes cancer or mutations
- Identify data gaps in toxicity information

### Exposure Analysis

- Identify people exposed
- Identify routes of exposure
- Estimate how much each person would receive by each exposure route using both routine and extreme case scenarios
- Estimate frequency and duration of exposure
- Calculate doses

### Risk Analysis

- Compare doses to NOELs and $LD_{50}$s and discuss probability of acute and chronic effects (including birth defects) for routine, extreme, and accident scenarios
- Conduct extreme case analysis for cancer risk
- Identify extreme case risk of mutations

## Human Health Hazard Analysis

The human health hazard analysis section (appendix B, section B2) describes the potential human health effects associated with each insecticide. Evaluations of these potential effects are generally based on results of toxicity tests in laboratory animals. These data are supplemented by data on actual human exposure when it is available for a given chemical. Toxicological tests are divided into the following six categories:

- **Acute toxicity**—Acute toxicity studies are used to determine the median lethal dose ($LD_{50}$), which is the dose that kills 50 percent of the test animals. $LD_{50}$ studies usually involve a single dose of the test material. In addition, acute toxicity tests are also used to estimate dosage levels for longer term studies. Acute toxicity studies are usually conducted over a 1- to 14-day period, depending on the purpose of the study.

- **Subchronic toxicity**—Subchronic studies are designed to establish a level of dosing at which no effects are observed in the test animals—the no-observed-effect level (NOEL). Subchronic studies generally last 3 weeks to 3 months.

- **Chronic toxicity**—Chronic toxicity studies, generally conducted over a period of 1 to 2 years, are used to establish a NOEL. Chronic studies are useful in observing long-term effects of a chemical, particularly carcinogenic effects.

- **Reproductive/developmental toxicity**—Reproductive studies are conducted to determine the effect of a chemical on reproductive success, as indicated by fertility (production of germ cells), fetotoxicity (direct toxicity for the developing fetus), maternal toxicity, and survival and weight of offspring. Developmental studies (also called teratology studies) determine the potential of a chemical to cause malformation in an embryo or a developing fetus between the time of conception and birth.

- **Oncogenicity studies**—Oncogenicity studies examine the potential for a chemical to cause tumors, either cancerous (malignant) or nonmalignant, when consumed over the animal's lifetime. Data on tumor formation are used to determine a cancer potency value. This value is defined as the increase in likelihood of getting cancer from a unit increase (1 mg/kg/day) in the dose of a chemical.

- **Mutagenicity assays**—Mutagenicity assays are used to determine the ability of a chemical to cause physical changes (mutations) in the basic genetic material of an organism.

Figure 4-3 illustrates the relationships among toxicity reference levels; figure 4-4 shows a cancer potency curve.

Figure 4-3. Relationships Among Toxicity Reference Levels

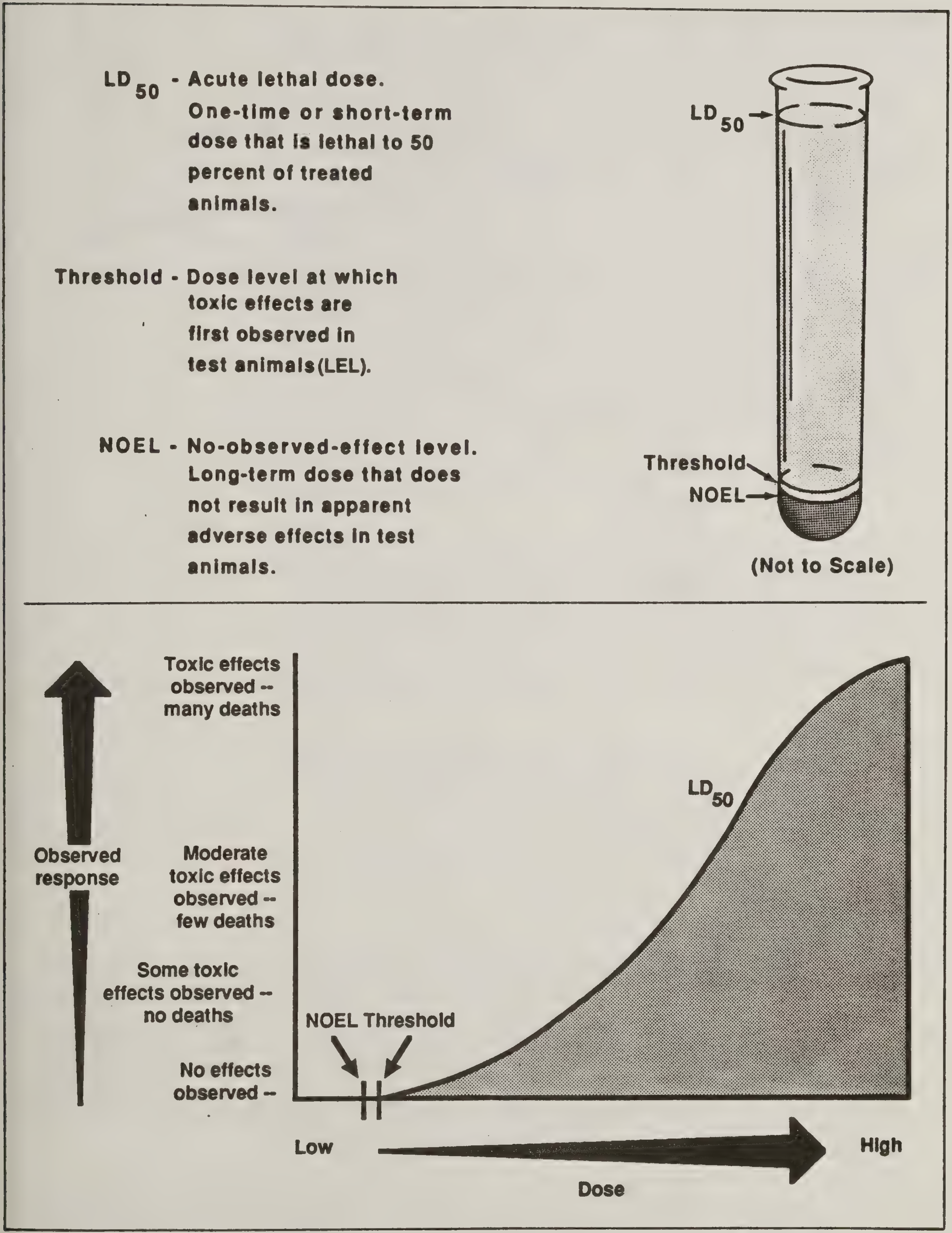
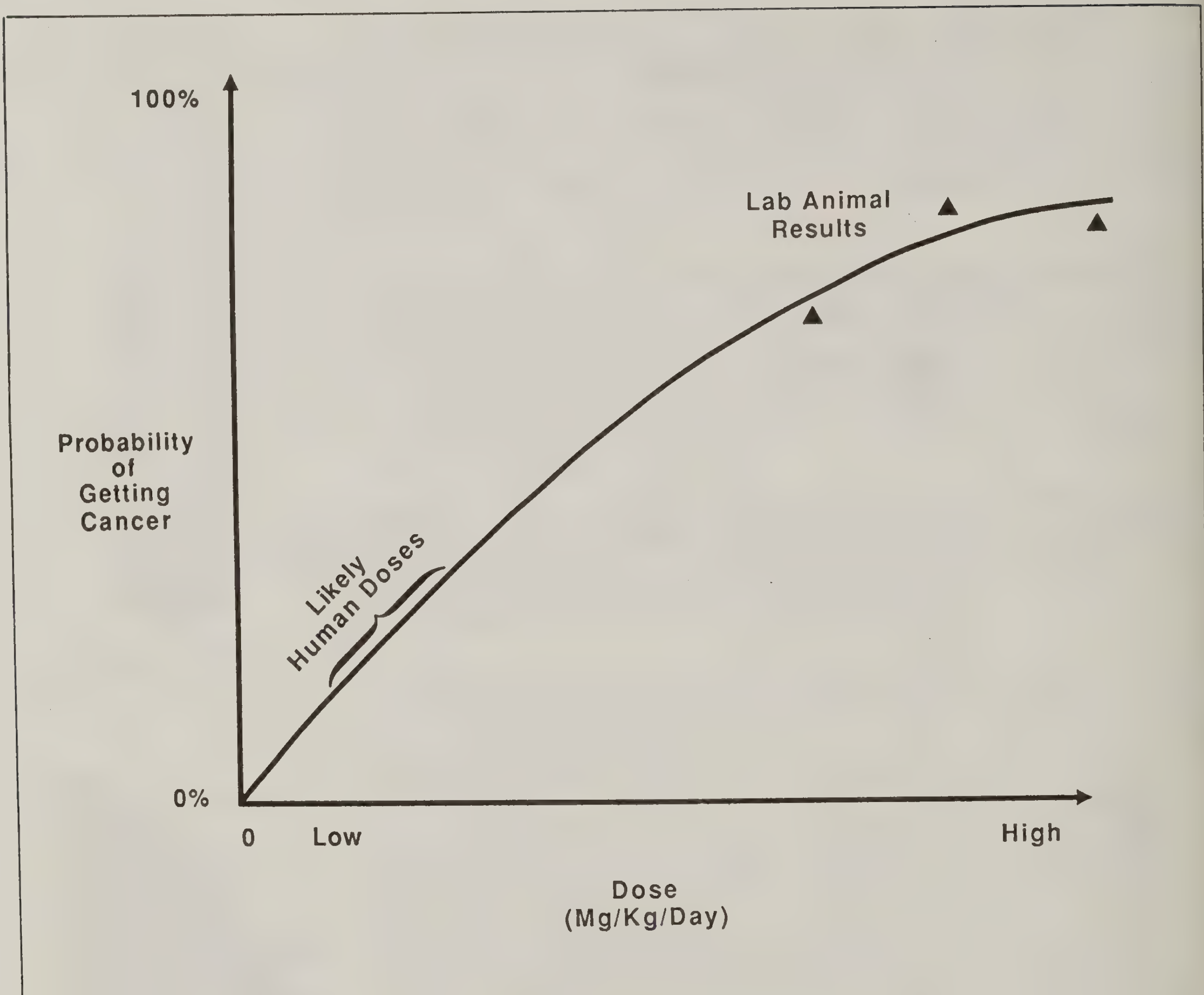


**Figure 4-4. Cancer Potency Curve**




The routes of administration of test material for laboratory animal toxicity testing are selected based on the most probable route of human exposure. In general, these routes of exposure include oral (by consumption of feed mixed with test material), dermal (application of the test material to the skin), and inhalation (exposure through breathing vapors or aerosol fumes). Levels of exposure (or doses) are expressed as milligrams of the chemical per kilogram of body weight (mg/kg/body weight) of the test animal.

The reference dose (or acceptable daily intake) is an estimate (with uncertainty spanning perhaps an order of magnitude) of daily exposure of the human population, including sensitive subgroups, that is not

likely to have an appreciable risk of deleterious effects during a lifetime (EPA, 1988e). The reference dose, established by EPA, is selected using the lowest NOEL from the most relevant species. An uncertainty factor of 100 is usually applied (10 to account for variation within humans and 10 for extrapolation from animals to humans). The reference dose value is relevant in this discussion of the toxicity of the boll weevil insecticides because it provides a useful point of reference by which to gauge potential exposures of workers and the general public.

The acute oral $LD_{50}$ values in rats for each chemical are summarized in table 4-8. In addition, table 4-8 presents two types of NOELs for each chemical. The first type of NOEL is for general systemic effects, such as decreases in body weight and food consumption, gross or microscopic abnormalities in tissues, or changes in hematology and blood chemistry. The second type of NOEL is for reproductive or developmental effects. Table 4-8 also presents cancer potency values for insecticides that are considered to be carcinogens (cancer causing).

A brief toxicological profile of each boll weevil insecticide and one inert ingredient is presented below.

*Malathion.* Malathion has a moderate acute toxicity, with an $LD_{50}$ in rats of 370 mg/kg (NIOSH, 1987). The reference dose (acceptable daily intake) for malathion is based on a 7-week oral toxicity study in humans that determined a NOEL of 0.23 mg/kg/day (EPA, 1988f). This NOEL was used as the systemic effects NOEL in the risk analysis. Systemic effects from malathion exposure are primarily associated with cholinesterase (ChE) inhibition.

The reproductive NOEL used in this analysis is 25 mg/kg/day (EPA, 1988a). No teratogenic effects (or birth defects) were observed in laboratory animal studies. Reproductive effects (including reduced fertility) and fetotoxic effects (including reduced pup weights and survival) have been observed in laboratory animal studies (NIOSH, 1987). Based on equivocal results of a carcinogenicity study on malaoxon (a malathion metabolite) in rats, malathion was considered a potential carcinogen in this risk analysis. A cancer potency of 0.00376 was used in the carcinogenic risk analysis. There is insufficient evidence to determine the mutagenic potential of malathion, therefore, it is considered a mutagen in this risk analysis (EPA, 1988f).

*Azinphos-methyl.* Azinphos-methyl has a severe acute toxicity, with an $LD_{50}$ in rats of 4.4 mg/kg (EPA, 1986f). A human reference dose of 0.0013 mg/kg/day for azinphos-methyl is based on a 2-year feeding study in dogs that determined a NOEL of 0.125 mg/kg/day (EPA, 1988c). This NOEL was used as one of the two systemic effects NOEL in the risk analysis. A NOEL of 0.286 mg/kg/day was determined from a human volunteer study (Hayes, 1982). This NOEL was also used in the risk analysis. Systemic effects from azinphos-methyl exposure in laboratory animals are primarily associated with ChE inhibition. The reproductive NOEL used in this analysis is

**Table 4-8. Toxicity Levels Used in This Analysis**

| Insecticide | Acute oral $LD_{50}$ in rats (mg/kg) | Systemic NOEL (mg/kg/day) | | Reproductive/ developmental NOEL (mg/kg/day) | Cancer potency $(mg/kg/day)^{-1}$ |
|---|---|---|---|---|---|
| | | Human | Rat | | |
| Malathion | 370 | 0.23 | 5.0 | 25 | 0.00376 |
| Azinphos-methyl | 4.4 | 0.29 | 0.125[a] | 2.5 | 0.00039 |
| Diflubenzuron | <4,640 | NA | 1.0[a] | >8.0 | 0.01718 |
| Methyl parathion | 3.6 | 0.31 | 0.025 | 0.25 | — |
| Xylene (inert) | 4,300 | NA | 179.0 | 0.3 | — |

[a] This NOEL is based on a 2-year dog feeding study.

2.5 mg/kg/day (EPA, 1988b). Azinphos-methyl has demonstrated the ability to induce teratogenic effects (birth defects), including developmental abnormalities in the musculoskeletal system, and fetotoxic effects, including decreased pup survival (NIOSH, 1987). Based on inconclusive results of a carcinogenicity study in rats, azinphos-methyl was considered a potential carcinogen in this risk analysis. A cancer potency of 0.00039 was used in the carcinogenic risk analysis. Because azinphos-methyl has tested positive in studies for gene mutation, chromosomal effects, and unscheduled DNA synthesis, it was also considered a mutagen in this risk analysis.

***Diflubenzuron.*** Diflubenzuron has a slight acute toxicity, with an $LD_{50}$ in rats of 4,640 mg/kg (EPA, 1988g). A human reference dose of 0.02 mg/kg/day for diflubenzuron is based on a 1-year feeding study in dogs that determined a NOEL of 2 mg/kg/day (EPA, 1988c). A more conservative NOEL of 1 mg/kg/day, based on a 90-day feeding study, was used in this risk analysis (EPA, 1988f). Systemic effects in laboratory animals associated with diflubenzuron exposure include increased methemoglobin and sulfhemoglobin and degeneration of the liver.

The reproductive NOEL used in this analysis is >8 mg/kg/day (EPA, 1988e). Diflubenzuron has not demonstrated the ability to induce reproductive or developmental effects in laboratory animals. Therefore, the NOEL used in this risk assessment may overestimate risks of reproductive effects. Data from a mouse carcinogenicity study suggest that diflubenzuron may have the potential to induce a carcinogenic response in mammals; however, EPA has determined that there is insufficient evidence to determine diflubenzuron's potential. Because of this uncertainty, it was considered a carcinogen in this analysis. A cancer potency of 0.01718 mg/kg/day was used in the carcinogenic risk analysis. Because most mutagenic assays have revealed negative results, diflubenzuron is considered to be nonmutagenic.

***Methyl Parathion.*** Methyl parathion has a severe acute toxicity, with an $LD_{50}$ in rats of 3.6 mg/kg (EPA, 1988d). A human reference dose of 0.000025 mg/kg/day for methyl parathion is based on a 2-year feeding study in rats that determined a NOEL of 0.025 mg/kg/day (EPA, 1988d). This NOEL was used as one of the two systemic effects NOELs in the risk analysis. A study with human volunteers determined a NOEL of 0.31 mg/kg/day, which is the other NOEL used in this risk analysis. Systemic effects in laboratory animals associated with exposure to methyl parathion include ChE inhibition, decreased liver enzyme levels, and decreased organ weights.

The reproductive NOEL used in this analysis is 0.25 mg/kg/day (EPA, 1988d). Methyl parathion has demonstrated the ability to induce teratogenic and fetotoxic effects, including retardation and decreased weanling survival, respectively. Methyl parathion does not appear to be carcinogenic, based on laboratory animal studies; therefore, it was

not considered a carcinogen in this risk analysis. EPA (1986a) considers methyl parathion to be mutagenic.

***Xylene.*** Xylene (an inert ingredient in the Penncap M® formulation of methyl parathion) has a slight acute toxicity, with an $LD_{50}$ in rats of 4,300 mg/kg (NLM, 1987). A human reference dose of 2 mg/kg/day for xylene is based on a 2-year feeding study in rats that determined a NOEL of 179 mg/kg/day (EPA, 1988a). This NOEL was used as the systemic effects NOEL in the risk analysis. Systemic effects in laboratory animals associated with exposure to xylene include hyperactivity, decreased body weight gain, increased mortality, ChE inhibition, decreased liver enzyme levels, and decreased organ weights.

The reproductive NOEL used in this analysis is 0.3 mg/kg/day (NLM, 1988). Xylene has demonstrated the ability to induce teratogenic effects, including cleft palate. Data were unavailable on the carcinogenic potential of xylene. Xylene does not appear to be mutagenic, based on available mutagenicity study data; therefore, it was not considered a carcinogen in this risk analysis.

### Human Health Exposure Analysis

A detailed discussion of the methodology for estimating human exposures is presented in appendix B (section B3). The risk assessment examines the potential health effects to humans who might be exposed to insecticides as a result of activities associated with the boll weevil eradication and suppression programs. The exposed human population is divided into two groups. The first group—the public—includes passersby or nearby residents who could be exposed through the drift of insecticide spray droplets, through contact with sprayed vegetation, or by consuming food items, such as berries growing in or near cotton-producing areas and game animal meat or fish containing insecticide residues, or by consuming water that contains such residues. The second group—workers—includes applicators, supervisors, and other personnel directly involved in the application of insecticides.

To represent the entire range of possible exposures to workers and the public from boll weevil eradication and suppression operations, three levels of possible exposure were analyzed—routine-typical, routine-extreme, and accidental.

For routine-typical exposure estimates, a set of assumptions concerning the characteristics of typical insecticide applications was used to estimate the doses to workers and nearby members of the public that may potentially occur as a result of routine insecticide applications.

Routine-extreme exposure estimates are based on extreme values of the routine-typical application characteristics and should occur for less than 5 percent of all treatments. Routine-extreme assumptions are incorporated in the analysis to obtain the maximum exposure; these exposures are unlikely to be exceeded except in the case of an accident.

Because the potential for error exists in all human activity, accidental exposure levels were estimated for a number of accidental events that range in probability from unlikely to extremely unlikely.

### Public Exposures

Members of the public could be exposed to boll weevil insecticides through dermal, inhalation, and dietary routes. Mathematical modeling based on field study data (described in appendix B, section B3) was used to estimate residues from spray drift on the skin, in water, and on vegetation.

***Routine Public Exposures.*** Dermal and inhalation routes of exposure to the public were estimated using two scenarios. Direct dermal exposure to aerial spray drift was estimated assuming that members of the public were 500 feet directly downwind of the application area for the routine-typical case and 100 feet directly downwind of the application area for the routine-extreme case.

Dietary routes of exposure to the public were estimated using five items. These included eating 0.5 kg (approximately 1.1 pounds) of legumes, berries, or fish having drift residue; eating 0.5 kg (approximately 1.1 pounds) of venison from a deer that has received direct dermal exposure from insecticide spray (from distances of 25 and 0 feet for typical and extreme scenarios, respectively) and has consumed grass and water containing residues from distances of 25 and 0 feet for typical and extreme scenarios, respectively; and drinking 2 liters (approximately 2 quarts) of surface water that has received drift. Calculations for legumes, fish, or berries were based on the assumptions that they received drift at a distance of 100 feet (for the routine-typical case) and 25 feet (for the routine-extreme case).

***Accidental Public Exposures.*** Accidental exposures to the public were estimated using the following situations: drinking water from a reservoir that has received an accidental insecticide spill of 80 gallons from an aircraft, eating berries or fruit that have been directly sprayed, and receiving dermal and inhalation exposure from a direct spray.

***Lifetime Public Exposures.*** The carcinogenic risk to the public from the National Boll Weevil Cooperative Control Program was based on three exposure patterns—realistic, intermediate, and maximum. The realistic case was based on the average number of applications anticipated for boll weevil eradication or suppression. The maximum exposure scenario is based on the maximum estimated number of applications for a heavily infested area. Although the number of applications in this scenario may be high, it is also realistic in areas having severe infestations. The rationale for using the highest number of applications per year for the maximum exposure scenarios is to account for the worst case of exposure in order to be conservative and, therefore, provide the greatest margin for safety (MOS) in the carcinogenic risk analyses.

An additional intermediate exposure analysis was performed for a scenario in which the number of applications is the average of the number in the realistic and maximum exposure scenarios. Although this intermediate analysis is not based on a realistic application regimen within a boll weevil control program, it was performed to provide a measurement of sensitivity between the carcinogenic risk and the number of applications per year. Separate analyses for lifetime exposures from an eradication and a suppression program were conducted.

### Worker Exposures

Workers may be exposed dermally or by inhalation during routine operations, such as mixing and loading pesticides into application equipment or applying insecticides to cotton. Actual field worker monitoring studies were used to estimate doses to workers.

***Routine Worker Exposures.*** Doses to workers were estimated for the routine-typical, routine-extreme, and accidental scenarios for six types of workers: mixer/loaders, pilots, observers, monitoring team members, mist blower operators, and hiboy operators. For all worker scenarios, routine-typical exposures were calculated assuming average adjusted exposure rates based on field study data (described in appendix B, section B3) and application rates and frequencies estimated for the National Boll Weevil Cooperative Control Program.

***Accidental Worker Exposures.*** Accidental dermal exposure doses to workers were estimated using two scenarios: an accidental spill of one-half gallon of insecticide concentrate or formulation on the skin of the worker and an accidental spray from a broken hose.

***Lifetime Worker Exposures.*** Carcinogenic risk for workers is calculated based on an estimated maximum 30 years of employment involving pesticide application. Of the exposures the worker receives, 90 percent are assumed to be typical and 10 percent are assumed to be extreme.

### Uncertainty in the Human Health Risk Analysis

A number of factors contributed to the uncertainty in the process of evaluating risks to human health, including inherent uncertainties in the risk assessment process and uncertainties unique to the National Boll Weevil Cooperative Control Program.

An inherent uncertainty exists in relating dosage levels in animals to health risks in humans. To allow for the uncertainty from extrapolation of NOELs in laboratory animals to safe levels for humans, uncertainty factors of 10 were used to account both for interspecies differences (animals to humans) and for intraspecies differences (variations of sensitivity within the human population). The 100-fold safety factor (as previously discussed) was used in this analysis to evaluate acceptable risk levels for azinphos-methyl, diflubenzuron, and methyl parathion. A 10-fold safety factor was used in this analysis to evaluate acceptable

risk levels for malathion because dosage values are based on human, not animal, exposure studies.

It should be noted that the margin of safety (MOS) calculated from the estimated exposure and the NOEL is based on the dose level that produced no effects in laboratory animals or human volunteers. All the NOELs used in this risk analysis from laboratory animal studies are based on long-term exposure. Because most laboratory animal NOELs were established from daily exposures of up to 2 years, this comparison may tend to overestimate risks to humans. NOELs from human volunteer studies were established in studies lasting 4 to 7 weeks. These NOELs may be better suited for comparisons to public exposures. Although members of the public are not expected to receive daily exposures, repeated exposures during a person's life may occur in certain regions of the United States.

The frequency of applications in existing boll weevil control practices and the timing for implementing the program in various regions of the United States influence the degree of uncertainty in predicting lifetime exposures. Persons living in areas where current treatment (or application) intervals are frequent may experience significantly higher exposures than those living in regions where treatments are relatively infrequent.

In addition, people in regions that are implementing the National Boll Weevil Cooperative Control Program in the near future will have fewer exposures than those in regions that will not implement the program for another 20 years. For example, Northern Alabama may initiate the National Boll Weevil Cooperative Control Program in 1992. Based on existing practices, residents and workers will be exposed relatively infrequently—1.3 applications per year for the next 2 years. Assuming that the average application regimen is needed to eradicate the boll weevil, exposures in the Northern Alabama region could occur for approximately 5.5 years.

In contrast, the boll weevil program in the Southern Texas region may not begin until the year 2010. Assuming that existing practices continue until the program begins, residents and workers in this region may be exposed to an average of six treatments per year for 18 years before program implementation. This exposure, combined with the additional program exposure of 3 to 4 years (with four, eight, four, one, and one treatment(s) per year for each of the 5 years conservatively modeled), will result in 21 to 23 years of exposure. The exposure scenarios used in the quantitative risk estimate of systemic and reproductive health effects do not account for the differences in lifetime exposures over various regions of the United States; however, the comparison of the exposure estimates to NOELs based on long-term laboratory animal exposure does account for the greater lifetime exposures that may be experienced in certain regions. Lifetime exposure scenarios for carcinogenic risks do compensate for these regional differences, not only by evaluating lifetime exposure for the average expected number of

treatments, but also by evaluating carcinogenic risks using a maximum number of treatments that would be expected in the case of program failure.

Because the exact mechanisms and doses that cause cancer are not understood, chemicals that could induce cancer were assumed to have no threshold effects and no MOS comparable to that used to judge the risks of systemic or reproductive effects. Any dose of a chemical considered to be a potential carcinogen, no matter how small, was assumed to pose some risk of carcinogenic effects. Where evidence existed from a long-term study that a pesticide could induce an increase in tumor formation with increasing doses, a cancer potency value was derived from the laboratory animal study and adjusted for the differences in metabolism and lifetimes between the laboratory animals and humans. The cancer potency value multiplied by an estimated human lifetime dose provides an estimate of human cancer risk.

### The Human Health Risk Analysis

In the risk analysis, the estimates of doses to workers and the public for each scenario were compared with the toxicity levels described in the hazard analysis. These comparisons were then used to determine the risks to humans. This analysis includes both eradication and suppression exposures. For systemic and reproductive health effects analyses, the scenarios for eradication and suppression are the same.

For threshold effects (systemic and reproductive effects), the doses were compared to the NOELs determined in the most sensitive animal test species and human studies, where available. The NOEL is the highest dose producing *no effect* in laboratory test species or humans. A margin of safety (MOS), which is the NOEL divided by the estimated human dose, was computed to relate the doses and effects seen in laboratory animals or humans to estimated doses and possible effects in humans. For example, a laboratory animal NOEL of 20 mg/kg divided by an estimated human dose of 0.2 mg/kg gives an MOS of 100.

For all chemicals, systemic effects were evaluated on the basis of the lowest systemic NOEL established in 2-year feeding studies with dogs or rats. In addition, systemic effects were also evaluated on the basis of studies in human volunteers, when available. These studies were generally 4 weeks or less in duration. Reproductive effects were evaluated for all chemicals based on the lowest maternal, fetotoxic, or teratogenic NOEL found in a three-generation reproduction study or teratogenic study. The reproductive NOEL for diflubenzuron is based on the highest dose tested and may overstate risks.

For comparing estimated doses to laboratory animal NOELs, an MOS of 100 is generally recognized as safe for humans and is comparable to the 100-fold uncertainty factor that the Environmental Protection Agency (EPA) uses to establish reference doses (or acceptable intake levels) for humans. The 100-fold safety factor accounts for extrapolation from

animals to humans and for variability within humans. The larger the MOS (the smaller the estimated human dose compared to the NOEL), the lower the risk to human health. For comparison to the NOELs based on human studies, an MOS of 10 is considered safe for malathion and azinphos-methyl. For methyl parathion, EPA recommends a safety factor of 100 for this human study; therefore, an MOS of 100 is used in this analysis.

The larger the MOS (the smaller the estimated human dose compared to the animal NOEL), the lower the risk to human health. For MOSs based on laboratory animal studies, MOSs greater than 100 indicate negligible risk for the chemical; MOSs between 50 and 100 indicate a slight risk of low-level toxic effects, particularly to sensitive individuals; and MOSs between 10 and 50 indicate a slight to moderate risk of low-level toxic effects, especially in light of the uncertainty in extrapolating from laboratory test animal species to humans. An MOS of 1 to 10 indicates a moderate risk of health effects; however, for sensitive individuals, an MOS in this range may present a significant risk of health effects. When the estimated human exposure exceeds the animal NOEL (when an MOS for a chemical is negative), risk may be significant.

For comparisons to studies in humans, MOSs greater than 10 indicate negligible risks. MOSs between 10 and 1 indicate moderate risk, and MOSs less than 1 indicate significant risk to human health.

When an estimated dose exceeded a NOEL, the dose was divided by the NOEL and indicated with a negative sign. The result was not an MOS, but simply a negative ratio. A negative ratio did not necessarily lead to the conclusion that there would be human toxic effects because NOELs used in this risk analysis are based on no-effect levels in long-term animal studies. Estimated doses are not likely to occur often or on a daily basis. This applies particularly to doses that are not likely to occur more than once, such as accidental exposures to the public. Doses that greatly exceeded the NOEL also were compared to the insecticide $LD_{50}$ to evaluate the risk of severe effects and mortality. For the public, it may be more useful to compare the estimated doses to the NOELs from the human studies, as the length of exposures in these studies more closely matches expected public exposures.

An analysis of cancer risk was conducted for the insecticides that could be human carcinogens—malathion, azinphos-methyl, and diflubenzuron—by comparing estimates of lifetime dose with cancer potency estimates derived from laboratory animal study data. Cancer risk from the insecticides for the general public was calculated for 5 and 30 exposures over a lifetime. Cancer risks to workers from the insecticides were calculated for a routine case assuming 5 years of employment in pesticide applications and assuming 30 years of employment for an extreme case.

Mutagenic risk for these insecticides was evaluated on a qualitative, rather than quantitative, basis, with a statement of the probable risk based on the available evidence of mutagenicity and carcinogenicity in laboratory studies.

## Summary of Human Health Risk Analysis Results

Risks from control operations are summarized in table 4-9 for routine-typical public, routine-extreme public, routine-typical worker, and routine-extreme worker exposures and accidents. Carcinogenic risks from control operations also are summarized in table 4-9. For those chemicals for which both human and animal toxicity studies were available, the studies that indicated the highest risk (lowest NOEL values) are discussed. Both human and animal studies are included in appendix B, section B4.

### Malathion

***Risk of Systemic and Reproductive Effects.*** Based on human studies, all MOSs for typical malathion exposures to the public at control program rates are greater than 10. This indicates that no adverse systemic effects are expected to occur from typical malathion exposures.

MOSs for extreme exposures to malathion are greater than 10, with the exception of consumption of fish from a pond that has received drift at 25 feet. The MOS for this exposure indicates that a moderate risk of systemic effects exists. This risk can be reduced if the public is warned not to eat fish from ponds within 50 feet of treated fields.

For accidental scenarios, MOSs indicate moderate risks of systemic effects to the public from direct spray, spray drift at 25 feet, consumption of legumes that have been directly sprayed, and from consuming water from a reservoir that received an accidental spill. Precautions to reduce risk include cessation of spraying when a member of the public is seen within 50 feet of the treatment area, reminding the public to wash all fruits and vegetables before consuming them and not to consume fruits or vegetables located within 25 feet of the spray area, and avoiding drinking water from the contaminated reservoir until monitoring data indicate that it is safe.

MOSs for malathion indicate a moderate risk to observers and hiboy and mist blower operators from routine-typical exposures to workers. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. No risks of reproductive effects are expected from malathion exposures to workers. Risks to other workers are negligible for routine-typical exposures.

For malathion, all MOSs from routine-extreme exposures for workers are less than 10 with the exception of the pilot and the monitoring team. MOSs for these workers indicate negligible risks of systemic effects. MOSs for mixer/loaders indicate a moderate risk of systemic effects. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. MOSs indicate a significant

**Table 4-9. Summary of Highest[a] Public and Worker Health Risks From Control Operations by Chemical**

| Exposure scenarios | Malathion | | Azinphos-methyl | | Diflubenzuron | | Methyl parathion | | Xylene | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Typical | Extreme | Typical | Extreme | Typical | Extreme | Typical | Extreme | Typical | Extreme |
| **Public:** | | | | | | | | | | |
| Dermal and inhalation | C | C | E | E | E | E | E | C | E | E |
| Dietary | C | B | E | B | E | D | D | A | E | E |
| **Workers:** | | | | | | | | | | |
| Pilot | C* | C | D | C | E* | E | C | B | E | E |
| Mixer/loader | C* | B | C* | C | E* | E | B | B | E | E |
| Observer | C* | A | B* | A | E* | C | A | A | E | C |
| Monitoring team | C | C | E | E | E | E | D | D | E | E |
| Ground applicators | B* | A | A* | A | B* | A | A | A | B | A |
| **Accidents:** | | | | | | | | | | |
| Worker | | A* | | A* | | A* | | A | | A |
| Public | | B | | B | | E | | B | | C |

[a] When there is more than one risk category for an exposure scenario, only the highest risk category is included.

Notes: Risks for all chemicals except malathion are categorized as follows:

A = Significant risk—margin of safety is less than 1.
B = Moderate to significant risk—margin of safety is between 1 and 10.
C = Slight to moderate risk—margin of safety is between 10 and 50.
D = Slight risk—margin of safety is between 50 and 100.
E = Negligible risk—margin of safety is greater than 100.

Risks for malathion are categorized as follows:

A = Significant risk—margin of safety is less than 1.
B = Moderate risk—margin of safety is between 1 and 10.
C = Negligible risk—margin of safety is greater than 10.

* Indicates carcinogenic risk is greater than 1 in 1 million.

risk of systemic effects for observers and hiboy and mist blower operators. Risks to observers can be reduced to acceptable levels by wearing protective clothing. Risks to hiboy and mist blower operators can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application procedures.

MOSs for workers for an accidental spill of the concentrate and for the spray from a broken hose indicate a danger for severe adverse effects. The use of protective clothing and immediate washing of the skin following an accident would significantly reduce the risk of adverse health effects.

***Cancer Risks From Eradication Operations.*** Cancer risks to the public are less than 1 in 1 million for all exposures from malathion, under typical and extreme scenarios. Therefore, negligible cancer risks are expected to result from public exposures to pesticides at eradication rates.

For accidents, cancer risks to the public are less than 1 in 1 million for malathion.

For malathion, the cancer risk for pilots is approximately 5 in 1 million. For observers, the cancer risk is approximately 5 in 100,000. For mixer/loaders, the risk is approximately 1 in 100,000. For hiboy operators and mist blower operators, the risks are 2 in 10,000 and 1 in 10,000, respectively. Precautions prescribed to reduce systemic effects will also reduce cancer risks.

Cancer risk from worker accidents from malathion are approximately 5 in 100,000 from a spill or a broken hose. These risks would be reduced to greater than 1 in 1 million by wearing protective clothing and washing immediately following accidental exposure.

***Cancer Risks From Suppression Operations.*** Negligible cancer risks are expected to result from any public exposure to malathion during suppression operations. Cancer risks to the public from malathion are less than 1 in 1 million for all exposures, including accidents.

Cancer risks for workers from all exposures, including accidents, are in the same range as those observed for the eradication program. Therefore, there are no changes in the mitigation measures recommended for suppression from those measures recommended for eradication as a result of cancer risk.

***Risk of Mutagenic Effects.*** Available data on malathion indicate that malathion does not cause gene mutations; however, it may be a weak inducer of chromosomal breakage. EPA (1988a) has requested further studies to determine the mutagenic potential of malathion. This risk analysis uses the worst case assumptions: malathion is a mutagen for humans, and the risk of heritable mutations from malathion is no greater than its carcinogenic risk.

### Azinphos-methyl

***Risk of Systemic and Reproductive Effects.*** Risks from azinphos-methyl exposure calculated from human studies are described in appendix B, section B4.

Based on toxicity levels found in laboratory animal studies, all MOSs for typical public exposures to azinphos-methyl exceed 100. Therefore, no adverse systemic and reproductive effects are expected to occur from typical azinphos-methyl exposures.

MOSs for extreme public exposures to azinphos-methyl indicate slight risk of systemic effects from consuming berries that have received drift at 25 feet, a slight to moderate risk of systemic effects from consuming legumes that have received drift at 25 feet, and a moderate to significant risk of systemic effects from consuming fish that have received drift at 25 feet. These risks can be reduced if the public is warned not to eat fish from ponds within 50 feet of treated fields and reminded to wash fruits and vegetables before consuming them. Risks from consuming venison can be reduced if spraying is avoided when deer are present.

MOSs for accidental public exposures to azinphos-methyl indicate slight to moderate risks of systemic effects from consuming berries or legumes that have been directly sprayed, and from receiving dermal and inhalation exposures at 25 feet. MOSs indicate moderate to significant risks from being directly sprayed or from consuming water from a reservoir that received an accidental spill. Precautions to reduce risk include cessation of spraying when a member of the public is seen within 50 feet of the treatment area, reminding the public to wash all fruits and vegetables before consuming them and not to consume fruits or vegetables located within 25 feet of the spray area, and avoiding drinking water from the contaminated reservoir until monitoring data indicate that it is safe.

For typical worker exposures, MOSs for azinphos-methyl indicate a slight risk of systemic effects to pilots, and a slight to moderate risk to mixer/loaders. The MOSs indicate a slight to moderate risk of reproductive effects to mist blower operators. Moderate to significant risks of systemic effects are indicated by the MOSs for observers. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. For pilots, a sealed cockpit during application procedures may be substituted for protective clothing to achieve acceptable levels. The MOS is less than 1 for hiboy and mist blower operators, indicating a significant risk of systemic effects. Also, the MOS indicates a moderate to significant risk of reproductive effects to hiboy operators. Risks to ground applicators can be reduced to acceptable levels by operating in an enclosed cab or wearing protective clothing during application procedures.

All worker risks are below 100 for extreme azinphos-methyl exposures, with the exception of the monitoring team. MOSs for pilots and mixer/loaders indicate a slight to moderate risk of systemic effects. The MOSs for observers indicate a slight to moderate risk of reproductive effects and a significant risk of systemic effects. For these workers, the use of protective clothing would reduce the risk to acceptable levels. For pilots, a sealed cockpit during application procedures may be substituted for protective clothing to achieve acceptable levels. The MOSs for hiboy and mist blower operators indicate a moderate to significant risk of reproductive effects and a significant risk of systemic effects. Risks to hiboy and mist blower operators can be reduced to acceptable levels by operating in an enclosed cab or wearing protective clothing during application procedures.

For azinphos-methyl, MOSs for an accidental spill of concentrate and for spray from a broken hose indicate a danger for severe adverse effects. The dose received from these accidents is over 2 times greater than the laboratory animal $LD_{50}$; therefore, fatalities may potentially occur. As discussed above, washing immediately after contact and wearing protective clothing would significantly reduce the risk of adverse health effects.

***Cancer Risks From Eradication Operations.*** Cancer risks to the public are less than 1 in 1 million for all exposures from azinphos-methyl under typical, extreme, and accidental scenarios. Therefore, negligible cancer risks are expected to result from public exposures to azinphos-methyl at eradication rates.

Cancer risks to workers from azinphos-methyl in eradication operations are less than 1 in 1 million for all workers except mixer/loaders, observers, hiboy operators, and mist blower operators. Mixer/loaders have cancer risks of approximately 3 in 1 million. This risk is considered acceptable; however, wearing protective clothing would reduce this risk to levels less than 1 in 1 million. Observers have cancer risks of approximately 7.3 in 100,000. Hiboy and mist blower operators have risks of 4 in 100,00 and 2 in 100,000, respectively. Protective clothing or operating in an enclosed cab or vehicle would reduce these risks to less than 1 in 1 million.

Cancer risks for azinphos-methyl are 2 in 1 million for an accidental spill and for spray from a broken hose. Although these risks are considered acceptable, risks would be significantly reduced by washing following the accident and by wearing protective clothing.

***Cancer Risks From Suppression Operations.*** Cancer risks to the public are less than 1 in 1 million for all exposures from azinphos-methyl. For accidents, cancer risks to the public are less than 1 in 1 million. Therefore, negligible cancer risks are expected to result from any public exposure during suppression operations.

Cancer risks for workers are in the same range as those observed for the eradication program. Therefore, there are no changes in the mitigation measures recommended for suppression from those measures recommended for eradication as a result of cancer risks.

***Risk of Mutagenic Effects.*** Because azinphos-methyl has tested positive in studies for gene mutation, chromosomal effects, and unscheduled DNA synthesis, the assumption was made in this risk analysis that azinphos-methyl is mutagenic. The risk of heritable mutations from azinphos-methyl is assumed to be no greater than the carcinogenic risk that is calculated in this risk analysis.

### Diflubenzuron

***Risk of Systemic and Reproductive Effects.*** No studies were available on toxicity levels of diflubenzuron in humans; MOSs for diflubenzuron are based on laboratory animal studies only.

All MOSs for typical public exposures to diflubenzuron exceed 100. Therefore, no adverse systemic and reproductive effects are expected to occur from typical diflubenzuron exposures.

For the routine-extreme scenario, the MOS for the consumption of fish from a pond that has received drift at 25 feet indicates a slight risk of systemic effects to the public from diflubenzuron. All other MOSs are greater than 100, indicating that no adverse effects are expected to occur. The risk for fish consumption can be reduced to acceptable levels if the public is warned not to eat fish from ponds within 100 feet of the treatment area.

For diflubenzuron, MOSs for accidental public exposures indicate no risk of systemic or reproductive effects.

With the exception of hiboy and mist blower equipment operators, all MOSs are greater than 100 for typical diflubenzuron exposures. MOSs indicate a slight risk of reproductive effects to mist blower operators, a slight to moderate risk of reproductive effects to hiboy operators, and moderate to significant risks of systemic effects to both hiboy and mist blower operators. Risks to these workers can be reduced to acceptable levels by operating in an enclosed cab or wearing protective clothing during application procedures.

For diflubenzuron, all MOSs for extreme exposures to workers are greater than 100, with the exception of observers and hiboy and mist blower operators. The MOS for observers indicates slight to moderate risk of systemic effects. The use of protective clothing would reduce the risk to observer to acceptable levels. MOSs for mist blower operators indicate a slight to moderate risk of reproductive effects and a moderate to significant risk of systemic effects. MOSs for hiboy operators indicate a moderate to significant risk of reproductive effects and a significant risk of systemic effects. Risks to these workers can be

reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application procedures.

The MOS for worker accidents involving diflubenzuron indicates significant to severe risks of systemic and reproductive health effects. Washing immediately after contact and wearing protective clothing would significantly reduce the risk of adverse health effects.

*Cancer Risks From Eradication Operations.* A cancer risk was calculated for diflubenzuron because of the inconclusive nature of the available carcinogenicity studies and the conservative nature of this risk assessment. However, these uncertainties may lead to an overstatement of the cancer risks from the use of diflubenzuron.

Cancer risks to the public are less than 1 in 1 million for all public exposures from diflubenzuron under typical, extreme, and accidental scenarios. Therefore, negligible cancer risks are expected to result from public exposures to diflubenzuron at eradication rates.

For diflubenzuron, carcinogenic risks for pilots and mixer/loaders are approximately 1.2 and 3 in 1 million, respectively. These risks are considered acceptable but can be reduced to less than 1 in 1 million by wearing protective clothing. Cancer risks for observers are 1 in 100,000; protective clothing can reduce this risk to less than 1 in 1 million. Cancer risks for hiboy operators and mist blower operators are 5 in 10,000 and 2 in 10,000, respectively. Protective clothing or operating in an enclosed cab would reduce these risks to less than 1 in 1 million.

Cancer risks for worker accidents with diflubenzuron are approximately 6 in 10,000 for an accidental spill and 2 in 10,000 for spray from a broken hose. These risks may be reduced to less than 1 in 1 million by washing immediately following an accidental exposure.

*Risk of Mutagenic Effects.* Diflubenzuron has tested positive for direct DNA damage and weakly positive for mitotic recombination; however, it has also tested negative in several studies for gene mutation, chromosomal effects, and DNA repair and recombination. Because most mutagenic assays have revealed negative results, diflubenzuron is considered to be nonmutagenic.

### Methyl Parathion

*Risk of Systemic and Reproductive Effects.* Risks from methyl parathion exposure calculated from human studies are described in appendix B, section B4.

Based on laboratory animal studies, MOSs for routine-typical exposures indicate slight risk of systemic effects for the consumption of 0.5 kg/day of venison, assuming the deer received a dermal drift dose at 25 feet and consumed forage and water receiving drift at 25 feet. This risk can be reduced if spraying when deer are present is avoided.

MOSs for typical exposures to xylene (an inert ingredient in the methyl parathion formulation Penncap M®) follow.

For methyl parathion, MOSs indicate a slight to moderate risk from extreme exposures, including dermal and inhalation drift at 100 feet; consumption of water that has received drift residues at 25 feet; and consumption of venison from a deer that has been directly sprayed, has consumed forage with drift residues at 25 feet, and consumed water from the pond. The MOSs for consumption of berries and legumes that have received drift residues at 25 feet indicate a moderate risk of systemic effects. For reproductive effects, consumption of berries and legumes indicates a slight and moderate risk, respectively. The MOS for consuming fish from a pond that has received drift at 25 feet indicates a significant risk of systemic and reproductive effects. The MOS for systemic effects from consuming fish is -2, meaning the dose exceeds the NOEL for this chemical. The dose, however, is only 2 percent of the laboratory animal $LD_{50}$ for methyl parathion.

These risks can be reduced if the public is warned not to eat fish from ponds within 50 feet of treated fields and reminded to wash fruits and vegetables before consuming them. Risks from consuming venison can be reduced if spraying is avoided when deer are present.

For accident scenarios, the MOSs indicate slight to moderate risks to the public of reproductive effects from receiving a dermal and inhalation dose at 25 feet, being directly sprayed, consuming berries or legumes that received direct spray, and from consuming water from a reservoir that received an accidental spill. Moderate to significant risks of systemic effects may occur from receiving a dermal and inhalation dose at 25 feet, being directly sprayed, consuming berries or legumes that received direct spray, and from consuming water from a reservoir that received an accidental spill. Mitigation measures as described above for malathion and azinphos-methyl will reduce risks for methyl parathion to acceptable levels.

The MOS for typical exposures for all workers using methyl parathion is less than 100. MOSs for typical exposures indicate a slight risk of systemic effects to the monitoring team. MOSs for pilots indicate a negligible risk of reproductive effects and a slight to moderate risk of systemic effects. MOSs for typical exposures to mixer/loaders indicate a slight to moderate risk of reproductive effects and moderate to significant risks of systemic effects. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. For pilots, a sealed cockpit during application procedures may be substituted for protective clothing to achieve acceptable levels. MOSs indicate significant risks of systemic effects to observers and moderate to significant risk of reproductive effects. The use of protective clothing would reduce the risk to observers to acceptable levels. MOSs for hiboy and mist blower operators indicate moderate to significant risks of both reproductive effects and significant risks of systemic effects. Risks to these workers can be reduced to acceptable levels by

operating in an enclosed cab and/or wearing protective clothing during application procedures.

For extreme exposures to methyl parathion, all MOSs for workers are less than 100. The MOS for the monitoring team indicates a slight risk of systemic effects. MOSs for pilots indicate a slight risk of reproductive effects and a moderate to significant risk of systemic effects. MOSs for mixer/loaders indicate a slight to moderate risk of reproductive effects and a moderate to significant risk of systemic effects. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. For pilots, a sealed cockpit during application procedures may be substituted for protective clothing to achieve acceptable levels. The MOSs for observers indicate a significant risk for both reproductive and systemic risks. Risks to observers can be reduced to acceptable levels by operating in an enclosed vehicle or other structure and wearing protective clothing during application procedures. The MOSs for hiboy operators and mist blower operators indicate a significant risk for both reproductive and systemic risks. For the hiboy operator, the MOS is significantly less than 1, and is approximately 50 percent of the laboratory animal $LD_{50}$; therefore, exposure to the hiboy operator could present a danger of severe, adverse health effects. Risks to mist blower operators can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application procedures. Additional precautions, such as using extreme caution when leaving the cab following spraying operations, must also be followed to reduce the risks to hiboy operators.

For methyl parathion, MOSs for an accidental spill and a broken hose indicate a severe danger of adverse effects. The dose received in the event of an accidental spill is 18 times greater than the $LD_{50}$. The dose received in the event of a spray with a broken hose is 9 times greater than the $LD_{50}$. Based on the comparisons with laboratory animal $LD_{50}$s, there is potential for fatalities. The use of protective clothing and washing immediately following exposure would significantly reduce the risk of adverse systemic and reproductive effects.

***Cancer Risks From Eradication and Suppression Operations.*** A cancer risk assessment was not performed for methyl parathion because there is insufficient information for conducting a quantitative cancer risk analysis.

***Risk of Mutagenic Effects.*** EPA (1986a) considers methyl parathion to be mutagenic. Although methyl parathion is assumed to be mutagenic in this risk analysis, the probability of it causing heritable mutations is considered to be low because it has not demonstrated the ability to cause cancer in mammals.

### Xylene

***Risk of Systemic and Reproductive Effects.*** No studies were available on toxicity levels of xylene in humans; systemic MOSs for xylene are based on laboratory animal studies only.

MOSs for xylene indicate a slight risk to the public of reproductive effects from consuming water from a reservoir that has received an accidental spill. Water from a reservoir that has received an accidental spill of methyl parathion (and thus xylene) should not be consumed until monitoring data indicate that it is safe.

The MOSs for typical worker exposures to xylene are greater than 100 in all cases except for hiboy and mist blower operators. For these workers, MOSs indicate a moderate to significant risk of reproductive effects to mist blower and hiboy operators. Risks to these workers can be reduced to acceptable levels by following the same procedures suggested to reduce the risks of methyl parathion.

The MOSs for extreme worker exposures to xylene are greater than 100 for all workers except observers, hiboy operators, and mist blower operators. For observers, the MOS indicates a slight to moderate risk of reproductive effects. For mist blower operators, the MOS indicates a moderate to significant risk of reproductive effects. For hiboy operators, the MOS indicates a significant risk of reproductive effects. Protective measures prescribed for methyl parathion will also reduce the risks from xylene.

MOSs for accidental exposures to xylene indicate a slight to moderate risk of systemic effects and a significant risk of reproductive effects. The precautionary measures previously discussed for methyl parathion also will significantly reduce the risk of adverse health effects for xylene exposure.

***Cancer Risks From Eradication and Suppression Operations.*** A cancer risk assessment was not performed for xylene because no data on the carcinogenicity of xylene are available.

***Risk of Mutagenic Effects.*** Available evidence from mutagenicity data on xylene indicates that it is not mutagenic; therefore, xylene is assumed to be nonmutagenic in this analysis.

## Summary of Impacts on Human Health by Program Alternative

### No Action

Under the no action alternative, current grower practices would continue with no APHIS involvement. More than 14 insecticides currently are used to control boll weevils. Safeguards are provided to the extent that an individual grower adheres to EPA label requirements and State regulations. The health effects of this alternative cannot be quantified because it is not known which chemicals would be used, the application rates for these chemicals, the treatment schedules, and what, if any,

control measures would be selected by individual growers. However, these effects may be discussed qualitatively based on the risk analysis results.

For systemic and reproductive health effects, the program risk analysis for the boll weevil insecticides approximates the effects that would be expected under the no action alternative, although growers may use different chemicals than those analyzed in this EIS. Unlike the eradication alternative, however, chemical use in the no action alternative would continue every year with no projected termination date. In addition, under the no action alternative, growers may treat less often (an average of 2.8 treatments per year). This is difficult to quantify from treatment data, however, because of the difficulty in distinguishing between boll weevil treatments and treatments for other pests. However, because time intervals are not incorporated in the risk analysis for systemic and reproductive health effects and because the exposures are compared to long-term exposure NOELs in laboratory animals, the analysis may compensate for the extended length of exposure that would occur for an indefinite time interval from the continued chemical treatments by individual growers.

For carcinogenic effects, the risk analysis for the suppression program analyzes the use of insecticides at the same rate for 30 years (although the cooperative suppression program would have no finite termination date), compared to the carcinogenic risk analysis for eradication, which incorporated the use of insecticides for shorter intervals. For this reason, the carcinogenic analysis for suppression is likely to present results most analogous to the carcinogenic risk under the no action alternative.

Additional uncertainties in predicting health effects under the no action alternative result from the uncertainties of the specific chemicals that would be used. The synergistic and cumulative effects resulting from the use of multiple chemicals may cause the health risk of the no action alternative to be greater than the suppression or eradication alternatives. Additional analysis of cumulative and synergistic effects is provided in a later section of this chapter.

Also, under the no action alternative it is likely that 4.5 million acres that are now weevil free would become reinfested. This reinfestation would necessitate a significant increase in the amount of insecticides used in those areas, with associated concerns for human health.

### Beltwide Eradication

Under the beltwide eradication alternative (both full and limited Federal involvement), risks of health effects for exposed individuals would be the same as those quantified for eradication operations. Under the eradication alternative, applications may be more frequent for a relatively shorter time. In the short term, the overall risks of health effects are generally similar for the suppression and eradication programs.

Over the long term, however, risks would be potentially greater in the suppression program because such a program may be implemented indefinitely.

The duration of an eradication program is less than that of a suppression program: 3½ years for eradication, as opposed to an indefinite number of years for suppression. Thus, an eradication program would be expected to have a lower lifetime estimated exposure and a lower risk of long-term health effects than the suppression program.

Implementation dates for the eradication program would vary by region. Thus, the public and workers in some regions will have less exposure than those in other regions. For example, some regions of the Cotton Belt may not implement the eradication program for 19 years; these regions are assumed to continue current treatment practices until program implementation. Exposures in these regions could be extended for approximately 22½ years (19 years for interim grower treatments, plus 3½ years for the eradication program). In regions where implementation may begin in only 2 years, the number of years of exposure to interim grower treatments is substantially reduced. Hence, the risk of systemic, reproductive, and carcinogenic health effects would be greater in regions with longer term exposures.

Because the risk analysis for systemic and reproductive effects compares estimated exposures to NOELs from long-term animal studies, the risks to the public in regions with longer exposures would not be expected to exceed the risks predicted in the risk analysis for the eradication program. The carcinogenic risk analysis does compensate for regional differences in lifetime exposure by estimating a maximum exposure that would be expected only in the case of program failure. In all likelihood, the maximum exposure exceeds the greatest lifetime exposure that would occur in any region of the Cotton Belt. Carcinogenic risks in any region of the Cotton Belt would not be expected to exceed those risks predicted in the carcinogenic risk analysis.

### Beltwide Suppression

Under the suppression alternative (both full and limited Federal involvement), risks of health effects would approximate those described in the risk analysis for suppression operations. Although the suppression program may in the short term have fewer applications than the eradication program, the overall risks of health effects are generally similar for the suppression and eradication programs over the short term.

Because implementation of the program in various regions would occur at various times, the general public and workers in some regions would have less exposure than others. In general, long-term exposures would be greater in the suppression program because treatments are continued over a longer period of time. Treatments in the suppression program may continue indefinitely, while treatments in the eradication program

may continue for only 3½ years. The risks of systemic and reproductive health effects are not expected to exceed those risks predicted in the risk analysis for suppression operations because estimated exposures were compared to long-term animal data (as previously discussed). Carcinogenic risks are analyzed using lifetime exposure scenarios that account for long-term repeated exposures that may occur in the suppression program. The carcinogenic risks would not be expected to exceed the risk predicted in the maximum exposure scenario in the risk analysis for suppression operations even in areas where the program may not be implemented for 20 years.

## Air Quality

The potential impacts of boll weevil control activities on air quality include slight increases in fugitive dust from cultural control activities and slight increases in concentrations of criteria pollutants (described below) from the internal combustion engines of the vehicles, airplanes, and machinery used in boll weevil control activities. The risks of insecticide drift have been discussed in the sections on human health, wildlife, and aquatic systems.

Criteria pollutants—pollutants for which maximum allowable emission levels and concentrations are enforced by State air control agencies—will be produced by fuel combustion in airplanes, vehicles, and machinery used in boll weevil control activities. The amounts of these pollutants should have a negligible effect on air quality except on a localized or temporary basis. Increases in ozone concentrations from the volatilization of insecticides are also expected to be negligible. All chemicals considered for aerial or ground application have very low vapor pressures and are essentially nonvolatile. Airborne particles of the insecticides are not readily photodegraded and are not expected to contribute to the formation of photochemical smog.

Although vegetable oil—which is used as a carrier in diflubenzuron application—has a relatively high vapor pressure, it contains a minimal amount of volatile and photochemically active hydrocarbons. Therefore, the use of vegetable oil as a carrier is not expected to contribute significantly to the formation of photochemical smog.

## Noise

Noise levels from boll weevil control activities will be greatest when aircraft are used to apply insecticides. Equipment and machinery for ground application of insecticides and cultural control implementation also will increase ambient noise levels.

The maximum noise level for propeller aircraft and helicopters at 100 feet is expected to exceed 100 decibels (dB) (USAF, 1984). However, the duration of noise at this level is limited during several treatment passes of the aircraft.

Human response to excessive noise levels includes annoyance, speech interference, sleep interference, and hearing loss. Most people are annoyed if noise levels exceed 80 dB, primarily because the noise interferes with speech or television viewing (Newman and Beattie, 1985). Noise from program activities is not expected to interfere with

sleep because spraying operations will be conducted only during daylight hours. Although hearing loss has been shown to be caused by prolonged and repeated exposure to noise levels exceeding 75 dB (NAS, 1977), prolonged exposure is not anticipated as a result of program activities.

Domestic animals and wildlife differ in their response to excess noise. Domestic animals have demonstrated an ability to adapt to intermittent aircraft noise under 120 dB with no adverse effects (Fletcher and Busnel, 1978). Potential adverse effects of noise exposure on wildlife include stress, interference with communication, reduced reproductive success, and a reduction in numbers within the area affected by the noise. The impact of noise will be greater if the animal is unaccustomed to noise, if the noise occurs suddenly, or if the noise is of long duration (Fletcher and Busnel, 1978).

## Visual Resources

The broad expanse of agricultural land in the Cotton Belt accents distant visually appealing land features, but it also tends to highlight the presence of control activities and equipment.

Insecticide applications will have minimal impact on visual resources; any impacts would be localized and temporary. The impacts of insecticide drift and mitigation measures to reduce drift are discussed earlier in this chapter. People in communities engaged in cotton production are accustomed to the sight of aircraft and agricultural equipment used in pest control activities, although a few people would consider these a visual intrusion.

Some individuals may find the fluorescent yellow-green pheromone traps visually unappealing and distracting. The bright, unnatural color of the traps does not readily blend with surrounding vegetation.

Nonchemical control methods are not expected to significantly affect the aesthetic appeal of cotton-producing areas. Agronomic practices such as postharvest stalk destruction may result in a dramatic change in the appearance of an area, but this change is consistent with the seasonal changes that occur in all agricultural environments as a result of harvesting and planting operations.

## Costs of Boll Weevil Controls

This section describes the methodology and assumptions used to estimate costs for each boll weevil control method and program alternative described in chapter 2. The materials, equipment, and labor requirements needed to implement each of the five control methods are presented, along with the costs of each. Estimated costs of the program alternatives are calculated using the control method costs applicable to each alternative. All costs are in 1987 dollars. All infested acreage is included in both the eradication and suppression program alternatives.

Treatment in both the full and limited Federal involvement eradication program alternatives would continue for a total of 3½ years in each geographic area. Initial modified diapause treatment would be applied in the fall of year 1 (½ year), followed by 2½ years of active treatment

and 1 year of post-program surveillance. Suppression treatments would continue indefinitely under the full Federal involvement program alternative. With limited Federal involvement in a suppression program, treatment would continue for a total of 3 years in each area: initial modified diapause in year 1 (½ year), followed by 2½ years of active treatment.

## Control Method Costs

The methodology used to evaluate costs for the cultural, mechanical, sterile insect release, and chemical control methods is described below. Dollar values are based on USDA beltwide boll weevil eradication cost estimates (USDA, 1988a), unless noted otherwise.

Regional costs of boll weevil control vary considerably throughout the Cotton Belt and depend to some extent on factors that cannot be predicted (for example, weather and the level of infestation). The costs used to estimate total program costs represent beltwide averages. The range of variation in cost components are noted below; these regional differences could be incorporated into cost estimates for site-specific environmental assessments.

Many of the boll weevil control costs are dependent on the length of the cotton-growing season. For these calculations, the growing season is defined as the 30 weeks from June to December.

### Cultural Control

Cultural control methods include the use of short-season cotton varieties, stalk destruction, trap cropping, and crop rotation. Stalk destruction is required by some State agricultural agencies, but individual cotton growers determine which of the other methods to use for boll weevil control. Without a survey of all growers' cultural control practices, the total costs of these methods cannot be estimated.

APHIS recommends using cultural methods but does not provide funding for their implementation. Incentive payments for cultural control methods may, however, be provided by other groups. For example, in 1987, if farmers destroyed cotton stalks in infested fields soon after harvesting, the Southeastern Boll Weevil Eradication Foundation gave them credit toward the following year's charge for boll weevil control. Farmers in program areas in Georgia, Florida, and Alabama who destroyed stalks by September 30, 1987, were credited $7.50 per acre; if they destroyed stalks by December 1, they were credited $5 per acre (according to a personal communication with Fred Planer, Program Director, USDA/APHIS, September 1988). Thus, the credit for destroying stalks by September 30 was equivalent to 2½ treatments if the stalks had not been shredded. The program saved funds because nearly all fields would have required at least 2½ treatments from September 30 to the end of the season. Early stalk destruction eliminated the need for many of these treatments.

The relative costs of cultural control methods across program alternatives can be compared even though dollar costs are unavailable. The

ranking shown along the first line in table 4-10 shows the effect of differences in the program alternatives on the magnitude of costs that the cotton growers would bear. Use of the mechanical, sterile insect, and chemical control methods may result in less dependence on cultural methods. Conversely, the no action alternative may cause growers to implement more cultural control methods because APHIS assistance for boll weevil control methods would be eliminated.

***Effects of Cultural Control Methods on Cotton Yield.*** Production of short-season cotton, stalk destruction, and trap cropping are expected to result in a declining boll weevil population and a corresponding increase in cotton yield. Crop rotation would have little if any effect on yield if the same number of acres were planted in comparable conditions (for example, soil fertility and moisture) in alternate locations.

***Effects of Cultural Control Methods on Cotton Revenue.*** Short-season cotton lint is generally of lower quality than the standard variety and, as such, its market price is lower. The revenue loss caused by this lower market value may be offset by the decreased cost of production expected with cultural control methods. Similarly, grower costs associated with stalk destruction and trap cropping may be offset by the increase in cotton revenues. Expected cotton revenues associated with crop rotation could increase or decrease depending on the fertility of the fields being used each season.

## Mechanical Control: Mass Trapping

Boll weevil trapping is appropriate as a control method only in areas with low weevil population densities. Federal funding would be provided only under the eradication program alternative.

***Proportion of Acreage Treated.*** Mechanical control would not be used in year 1. The number of acres on which traps might be used as a control method in year 2 of an eradication program is estimated to be 0.135 percent of the total infested acreage. In year 3, 2.275 percent of the acres might be trapped, but in year 4 of an eradication program (post-treatment surveillance), it is unlikely that any acres would be trapped for this purpose.

These percentages were derived assuming the population density of boll weevils can be represented by a Gaussian distribution and that the cotton acreage with densities sufficiently low for physical control in year 2 are three standard deviations below the mean. In year 3, the number of acres with sufficiently low population densities is assumed to be two standard deviations from the mean.

In a Gaussian distribution, the population density of boll weevils is a random variable x, normally distributed with mean $\mu$ and standard deviation $\sigma$, and 99.73 percent of the values of x deviate less than three standard deviations from the mean (Brennan, 1973). Thus, 0.27 percent of the values are more or less than three standard deviations from the mean. Intensive trapping is used only for low population densities, so

**Table 4-10. Summary of Costs of Program Alternatives (thousands of dollars)**

| Control method | No action | Program alternative | | | |
|---|---|---|---|---|---|
| | | Eradication | | Suppression | |
| | | Full | Limited | Full | Limited |
| Cultural[a] | 5 | 1 | 2 | 3 | 4 |
| Mechanical | X[b] | $2,764 | $2,764 | X[b] | X[b] |
| Sterile insect | X[b] | $54,950 | $16,485 | X[b] | X[b] |
| Chemical | $0 | $416,667 | $183,431[c] | $2,813,998[d] | $205,839 |

[a] APHIS does not provide funding for cultural control methods; costs would be borne solely by cotton growers. The magnitude of these costs would vary depending on the control program APHIS implements; they are ranked here in ascending order: 1 is the least expensive, 5 is the most expensive.
[b] X = Not expected to be used in the control program.
[c] Trap survey costs. APHIS would not purchase or apply insecticides under this alternative.
[d] Costs for the first 30 years (same duration as limited Federal involvement in suppression program); total costs not estimated because program would continue indefinitely.

Note: Does not include other control costs (such as administrative costs, services, repairs, and supplies) not directly attributable to a treatment method.

only the proportion of acreage with values less than three standard deviations from the mean, 0.135 percent, is calculated for year 2. The acres for year 3 were calculated given that in a Gaussian distribution, 95.45 percent of the values deviate less than two standard deviations from the mean.

***Trap Costs.*** Costs for trap densities of three traps per acre were calculated. The costs associated with traps are dependent on the number used. Lures and traps are estimated at $5.60 per trap per season, based on 16 pheromone baitings per trap. A trapper's salary and benefits total $194 per week during the 30-week season ($5.92 per acre); one trapper is needed for every 1,000 acres. Travel costs are estimated at $2.50 per acre per season.

### Sterile Insect Release

The release of sterile boll weevils has been shown to be effective as a control method only in areas with low weevil populations. In these areas, sterile boll weevils could be distributed 10 weeks of the 30-week season (per the Mississippi field trials). Federal funding would be provided under the eradication program alternative.

***Proportion of Acreage Treated.*** The use of sterile insects is limited by the current sterile insect production capacity at the Mississippi State University rearing facility, which is 5 to 6 million weekly. Construction of a larger facility would require 8 to 10 years and approximately $10 million. The costs of a new facility are not included in the program cost estimates.

With a distribution rate of 300 to 400 weevils per acre, as in the field trials, approximately 13,000 to 20,000 acres per week could be effectively treated. An average weekly production of 5.5 million weevils and an average weekly distribution of 350 weevils per acre was used to estimate program costs. Using these average rates, about 15,700 acres could be treated each week, for a cumulative total of 157,000 acres during the season.

***Sterile Insect Costs.*** The production and release of sterile boll weevils is estimated to cost between $20 and $30 per acre per season (according to a personal communication with Dr. D.D. Hardee, Lab Director, Stoneville, Mississippi, October 1988). In the calculation of program costs, an average of $25 per acre is used. This estimate includes the cost of the boll weevils, the labor and equipment required to distribute them, and monitoring traps to determine the number of sterile versus fertile weevils caught.

### Chemical Control

The four insecticides proposed for use under the chemical control method are malathion, azinphos-methyl, diflubenzuron, and methyl parathion. The total cost of the chemical control method consists of the cost of insecticides, contracts for aerial application of the insecticide

(which include the aircraft, pilots, and mixer/loaders), and salaries associated with monitoring and ground application.

*Proportion of Acreage Treated.* In an eradication or a suppression program, only those areas expected to support overwintering of the boll weevil would receive a modified series of diapause treatments. It is projected that approximately 20 percent of the program area would require such treatment in the fall of year 1 for an eradication program. In year 2, all infested acres would be treated in the eradication program, while only that acreage with boll weevil populations exceeding the economic threshold would be treated in a suppression program. The number of acres requiring treatment would be expected to decline by 50 percent in year 3 of an eradication program; for suppression, the acreage treated each year could remain relatively constant (personal communication, Fred Planer, Program Director, USDA/APHIS, January 1989).

This analysis assumed that 5 percent of the Cotton Belt acreage would not be treated aerially because of physical obstructions or proximity to sensitive areas. (Current program operations indicate that 2 percent may be more accurate.) These acres would be treated using ground equipment.

*Insecticide Costs.* The per acre cost of the insecticides considered for the program has ranged from approximately $1.69 to $6.62, based on previous bids by chemical companies (USDA, 1989). Diflubenzuron is generally more than twice as expensive as malathion, azinphos-methyl, and methyl parathion ($1.82, $2.23, and $1.69, respectively). These latter three may be used during the entire growing season, while diflubenzuron would be used only in June and July. Malathion was the only insecticide used in the 1988 APHIS Cooperative Boll Weevil Control Program (USDA, 1988b) and, because its cost represents a midpoint between the costs of the other two insecticides that can be used during the entire season, the program costs are calculated based on $1.82 per acre treated for insecticides. This figure assumes an application rate of 16 ounces per acre; 1 gallon will treat 8 acres. Up to an additional 5 percent is included for aerial trim spraying.

*Treatments.* An average of four diapause treatments per acre may be applied during year 1 of an eradication program and eight insecticide treatments per acre during year 2. This average may decrease to four in year 3 of the program. In order to estimate the number of treatments required in a suppression program, it was assumed that the number of treatments would be directly correlated with boll weevil population density. Because population densities may be expected to fluctuate over time in a cyclic pattern, it was assumed that the number of treatments would fluctuate in a cyclic manner over time. It is assumed that an average of five insecticide treatments would be applied in year 1, seven in year 2, five in year 3, four in year 4, and seven in year 5 in a full Federal involvement suppression program. This cycle would be repeated indefinitely. With limited Federal involvement, five

treatments would be applied in year 1, seven in year 2, and five in year 3.

*Aerial Application Costs.* Contract prices for aerial application range from $6.50 to $30.00 per gallon. Allowing an additional 5 percent for trim spraying, per acre costs can range from $0.85 to $3.94. Typical costs range from $2.50 to $3.00 per acre treated; the average of this range, $2.75, is used in calculating program costs. The range in costs is partially a result of economies of scale: aerial treatment costs for large areas are less per acre than for small areas. There are also regional differences in contract costs. Aerial application contractors provide the aircraft, pilots, and ground crew.

*Ground Application Costs—Mist Blower Trim.* The edges of some of the aerially treated cotton acreage are inaccessible by air, and will be treated by a mist blower mounted on the back of a truck rather than by aircraft. The acreage of these areas is estimated to be 10 percent of the aerially treated acreage.

The cost of the pesticide ($1.82 per acre) and the labor cost of application ($2.80 per acre) total $4.62 per acre treated. The pesticide cost would be the same as for aerial application. The wage of the mist blower operator is $7,000 per season; one operator would be required for each 5,000 acres of cotton treated using this equipment. The mist blowers and trucks are owned by the Federal Government.

*Ground Application Costs—Hiboys.* As noted above, approximately 5 percent of the cotton acreage requiring treatment each season will be treated using only ground equipment. The cost of the pesticide and labor is estimated at $4.62 per acre treated ($1.82 per acre for the chemical and $2.80 per acre for the hiboy operator). One hiboy operator at a wage of $7,000 per season would be required for every 1,000 to 1,500 acres of cotton not treated by aircraft or mist blower.

*Other Personnel Monitor Application Operations.* Salaries and benefits for these monitors are estimated at $0.06 per acre per application. (Travel costs for these personnel are included in "Other Control Costs.")

*Trap Surveying.* Boll weevil traps used to estimate population densities are assumed to be set at 1 per acre on average, recognizing that trapping would vary significantly across increments. The cost of lures and traps is $5.60 assuming 16 baitings per trap. One trapper may be needed for every 1,000 acres. At $194 per week for the 30-week season, this comes to $5.82 per acre of cotton with traps. Travel costs would be an additional $2.50 per acre.

### Other Control Costs

Expenses for other items not directly attributable to a treatment method are incurred regardless of the control method chosen. Some of these depend on the number of acres treated: $7.11 per acre for USDA personnel, travel, utilities, services, repairs, and supplies; and $3.33 per

acre for Field Unit Supervisors (one for each 5,000 acres of cotton at $16,630 per year). In addition to this total of $12.44 per acre, $1 million in miscellaneous costs are incurred each year of a program for staff ($700,000) and other expenses, such as rental equipment, and administrative, insurance, and attorney fees ($300,000).

### Postprogram Surveillance

Postprogram trapping to detect any reintroduction would usually begin in year 4 of each eradication increment. Trapping costs at a density of 1 trap per 10 acres are about $0.97 per acre, assuming 1 trapper for every 6,000 acres at $194 per week for 30 weeks. Lures and traps are estimated at $5.60 per trap per season; travel costs would be $2.50 per acre. In addition, one Plant Protection and Quarantine (PPQ) officer would be employed for every 80,000 acres to supervise trapping and communicate with cooperators during a critical 4-month period of each season. At a GS level 9/5 ($27,026 annually), this is equivalent to $0.11 per acre.

## Boll Weevil Control Program Alternative Costs

Under the no action alternative, no APHIS funds would be committed to boll weevil control. The present level of Federal funding for Cooperative Extension Service education and technical assistance cannot be determined within the perspective of this analysis.

The anticipated order in which States in the Cotton Belt will be treated in an eradication program is shown in table 4-11. Control programs in increments 1, 2, 3, 11, and 12 are already completed or under way; therefore, control costs were calculated beginning in 1992 with increment 4. Each new program increment will be added ½ year after completion of the previous increment; that is, the previous increment would be completed in the fall and a new increment added the following spring. (Preprogram mapping and placement of traps occur in the first spring). Based on 2½ years of treatment (including diapause for each of the remaining seven increments), a beltwide eradication program could be completed by 2013. (Figure 2-1, showing the increments for the eradication program, is presented in chapter 2.)

The order in which States are expected to be treated in a suppression program is shown in table 4-12. Treatment would continue indefinitely under the full Federal involvement program alternative, with each new program increment added 3 years after initiation of the previous increment. Under limited Federal involvement, each new program increment would be added ½ year after completion of the previous increment (as in the eradication program). A suppression program with limited Federal involvement could be completely implemented by 2021. (Figure 2-3, showing the increments for the suppression program, is presented in chapter 2.)

All acres infested by the boll weevil would be included in both the eradication and suppression programs. The acreage estimates used in the cost calculations are based on 1987 data (King et al., 1988); acreage included in the eradication program alternative for each increment is

**Table 4-11. Proposed Timing of Beltwide Boll Weevil Eradication**

| Increment | Geographic area | Start date[a] |
|---|---|---|
| 1 and 2 | North Carolina, Virginia, and South Carolina | Completed |
| 11 | Southern California and western Arizona | Completed |
| 3 | Georgia, Florida, and southern Alabama | Present Program Area |
| 12 | Eastern Arizona | Present Program Area |
| 4 | Northern Alabama and eastern Tennessee | 1992 |
| 5 | Western Tennessee, Arkansas, northern Mississippi, Missouri | 1995 |
| 6 | Southern Mississippi and Louisiana | 1998 |
| 7 | Oklahoma and northern Texas | 2001 |
| 8 | Eastern Texas | 2004 |
| 9 | Central Texas | 2007 |
| 10 | Southern Texas | 2010 |

[a] Based on the following assumptions:
— State legislation enabling eradication will be passed in each State, followed by a grower referendum, before the projected start date.
— Appropriation of Federal funds.

**Table 4-12. Proposed Timing of Beltwide Boll Weevil Suppression**

| Increment | Geographic area | Start date[a] |
|---|---|---|
| 3 | Georgia, Florida, and southern Alabama | 1992 |
| 12 | Eastern Arizona | 1992 |
| 1 and 2 | North Carolina, Virginia, and South Carolina | 1995 |
| 11 | Southern California and western Arizona | 1995 |
| 4 | Northern Alabama and eastern Tennessee | 1998 |
| 13 | Central California | 1998 |
| 5 | Western Tennessee, Arkansas, northern Mississippi, and Missouri | 2001 |
| 6 | Southern Mississippi and Louisiana | 2004 |
| 7 | Oklahoma and northern Texas | 2007 |
| 8 | Eastern Texas | 2010 |
| 9 | Central Texas | 2013 |
| 10 | Southern Texas | 2016 |
| 14 | New Mexico and western Texas (High Plains) | 2019 |

[a] Based on the following assumptions:
— State legislation enabling suppression will be passed in each State, followed by a grower referendum, before the projected start date.
— Appropriation of Federal funds.
— West Texas Containment Program continues until 2019.

shown in table 4-13. To estimate reinfested acreage to be included in a suppression program, it was assumed that a portion of the increments to be completed by 1992 (1, 2, 3, 11, and 12) and increments not currently infested (13 to 14) would become reinfested (table 4-14). The acreage, by increment, for the suppression program alternative is shown in table 4-15. Annual acreage by control method and increment is shown in appendix E.

Annual boll weevil eradication costs are summarized in table 4-16; suppression costs are shown in tables 4-17 and 4-18. (Annual costs by increment and cost component are presented in appendix E.)

### Summary of APHIS Costs

With full Federal involvement in an eradication or suppression program, the Federal Government could assume 30 percent of all program costs. The Federal Government could assume 30 percent of all costs other than insecticides and their application costs under limited involvement in an eradication program, and 30 percent of all costs for the 3-year suppression program (limited Federal involvement).

Total estimated APHIS costs range from $0 for the no action alternative to approximately $173 million for the eradication alternative with full Federal involvement. However, a suppression program with full Federal involvement would be the most expensive, because it would continue indefinitely. Although total costs were not estimated, costs for the first 30 years would be $1,616 million. Limited Federal involvement in an eradication program would cost about $103 million, and limited involvement in a suppression program would cost $275 million.

## Socioeconomic Impacts

Residents of communities where cotton is grown provide virtually all the labor necessary for boll weevil control, cotton production, and cotton ginning. Textile and cottonseed mills located in cotton-growing areas also employ residents of these areas.

### Impacts on Cotton-growing Communities

As more cooperative control programs are begun, additional jobs will become available for local residents, some of whom would otherwise be unemployed. A drastic increase in employment opportunities would not be expected, however, because of the relatively capital-intensive nature of cotton production and manufacture.

### Impacts on Cotton Growers

Cotton growers constitute the largest social group of the interested public who are likely to be affected by a boll weevil eradication or suppression program. Initiation of a cooperative beltwide control program resulting in greater cotton yield and lower boll weevil control costs for the growers would benefit these growers by providing higher profits. The savings to growers resulting from a portion of the control costs being borne by other entities would be greater in an eradication program than in a suppression program, especially in the long term.

The likely impacts on growers may be illustrated by results of the 1978–87 North and South Carolina cotton boll weevil eradication

## Table 4-13. Acreage Included in the Eradication Program

| Increment[a] | Geographic area | Acreage | |
|---|---|---|---|
| | | Program area | Infested |
| 4 | Northern Alabama | 208,400 | 200,000 |
| | Eastern Tennessee | | 8,400 |
| 5 | Western Tennessee | 1,130,500 | 103,600 |
| | Arkansas | | 600,000 |
| | Northern Mississippi | | 237,900 |
| | Missouri | | 189,000 |
| 6 | Southern Mississippi | 1,254,200 | 656,200 |
| | Louisiana | | 598,000 |
| 7 | Oklahoma | 155,000 | 115,000 |
| | Northern Texas: | | |
| | 1 (High Plains) | | 40,000 |
| 8 | Eastern Texas: | 332,500 | |
| | 4 (Rolling Plains) | | 15,000 |
| | 5 & 9 (Blacklands) | | 20,000 |
| | 8 (Blacklands) | | 25,000 |
| | 10 (Blacklands) | | 6,100 |
| | 11 (Central River) | | 86,000 |
| | 14 (Upper & Lower Coast) | | 180,400 |
| 9 | Western Texas: | 1,140,000 | |
| | 2 (High Plains) | | 130,000 |
| | 3 (Rolling Plains) | | 700,000 |
| | 6 (Trans Pecos) | | 60,000 |
| | 7 (Upper Concho) | | 250,000 |
| 10 | Southern Texas: | 357,000 | |
| | 12 (Lower Rio Grande) | | 320,000 |
| | 13 (Winter Garden) | | 37,000 |

[a] Does not include increments already participating in boll weevil cooperative eradication programs.

Source: King et al., 1988.

**Table 4-14. Reinfested Acreage Included in the Suppression Program**

| Increment[a] | Geographic area | Reinfested acres | | Percent of acres planted reinfested | 1987 acres planted |
|---|---|---|---|---|---|
| | | Geographic area | Total increment | | |
| 1 and 2 | North Carolina | 91,200 | 213,000 | 95 | 96,000 |
| | Virginia | 1,800 | | 100 | 1,800 |
| | South Carolina | 120,000 | | 100 | 120,000 |
| 3 | Georgia | 250,000 | 431,500 | 100 | 250,000 |
| | Florida | 29,500 | | 100 | 29,500 |
| | Southern Alabama | 152,000 | | | |
| 11 | Southern California | 20,500 | 38,100 | 50 | 40,900 |
| | Western Arizona | 17,600 | | 50 | 35,200 |
| 12 | Eastern Arizona | 172,900 | 172,900 | 50 | 345,800 |
| 13 | Central California | 555,000 | 555,000 | 50 | 1,110,000 |
| 14 | New Mexico | 40,000 | 270,000 | 50 | 80,000 |
| | Western Texas: | | | | |
| | 1 (High Plains) | 40,000 | | 50 | 80,000 |
| | 2 (High Plains) | 130,000 | | 50 | 260,000 |
| | 6 (Trans Pecos) | 60,000 | | 50 | 120,000 |

[a] Increments that have been previously eradicated or are currently uninfested.

**Table 4-15. Acreage Included in the Suppression Program**

| Increment | Geographic area[a] | Acreage | |
|---|---|---|---|
| | | Program area | Infested |
| 1 and 2 | North Carolina | 213,000 | 91,200 |
| | Virginia | | 1,800 |
| | South Carolina | | 120,000 |
| 3 | Georgia | 431,500 | 250,000 |
| | Florida | | 29,500 |
| | Southern Alabama | | 152,000 |
| 4 | Northern Alabama | 208,400 | 200,000 |
| | Eastern Tennessee | | 8,400 |
| 5 | Western Tennessee | 1,130,500 | 103,600 |
| | Arkansas | | 600,000 |
| | Northern Mississippi | | 237,900 |
| | Missouri | | 189,000 |
| 6 | Southern Mississippi | 1,254,200 | 656,200 |
| | Louisiana | | 598,000 |
| 7 | Oklahoma | 115,000 | 115,000 |
| 8 | Eastern Texas: | 332,500 | |
| | 4 (Rolling Plains) | | 15,000 |
| | 5 & 9 (Blacklands) | | 20,000 |
| | 8 (Blacklands) | | 25,000 |
| | 10 (Blacklands) | | 6,100 |
| | 11 (Central River) | | 86,000 |
| | 14 (Upper & Lower Coast) | | 180,400 |
| 9 | Central Texas: | 950,000 | |
| | 3 (Rolling Plains) | | 700,000 |
| | 7 (Upper Concho) | | 250,000 |
| 10 | Southern Texas: | 357,000 | 320,000 |
| | 12 (Lower Rio Grande) | | 37,000 |
| | 13 (Winter Garden) | | |
| 11 | Southern California | 38,100 | 20,500 |
| | Western Arizona | | 17,600 |
| 12 | Eastern Arizona | 172,900 | 172,900 |
| 13 | Central California | 555,000 | 555,000 |
| 14 | New Mexico | 270,000 | 40,000 |
| | Western Texas: | | |
| | 1 (High Plains) | | 40,000 |
| | 2 (High Plains) | | 130,000 |
| | 6 (Trans Pecos) | | 60,000 |

[a] Geographic areas as defined by King et al., 1988.

**Table 4-16. Boll Weevil Eradication Costs by Control Method (thousands of dollars)**

| Control method | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mechanical: Traps and trappers | 0 | 8 | 113 | 0 | 38 | 646 | 0 | 43 | 716 | 0 | 5 | 88 |
| Sterile insect technique: Steriles and distribution | 0 | 3,925 | 3,925 | 0 | 3,925 | 3,925 | 0 | 3,925 | 3,925 | 0 | 3,925 | 3,925 |
| Chemical: | | | | | | | | | | | | |
| Insecticide and application | 762 | 7,541 | 1,906 | 4,309 | 42,625 | 10,772 | 4,779 | 47,291 | 11,950 | 591 | 5,845 | 1,477 |
| Trap surveying | 2,280 | 2,784 | 2,784 | 13,066 | 15,737 | 15,737 | 15,321 | 17,458 | 17,458 | 2,904 | 2,158 | 2,158 |
| Other control costs | 1,417 | 3,087 | 2,044 | 3,360 | 12,798 | 6,900 | 3,617 | 14,089 | 7,544 | 1,324 | 2,618 | 1,809 |
| APHIS PPQ officer | 0 | 0 | 0 | 23 | 0 | 0 | 127 | 0 | 0 | 141 | 0 | 0 |
| Total program cost | 4,459 | 17,345 | 10,772 | 20,758 | 75,123 | 37,980 | 23,844 | 82,806 | 41,593 | 4,960 | 14,551 | 9,457 |
| Federal involvement | | | | | | | | | | | | |
| Full[a] | 1,338 | 5,204 | 3,232 | 6,227 | 22,537 | 11,394 | 7,153 | 24,842 | 12,478 | 1,488 | 4,365 | 2,837 |
| Limited[b] | 1,109 | 2,941 | 2,660 | 4,935 | 9,749 | 8,162 | 5,720 | 10,655 | 8,893 | 1,311 | 2,612 | 2,394 |

| Control method | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mechanical: Traps and trappers | 0 | 10 | 191 | 0 | 38 | 651 | 0 | 13 | 204 | 0 | 2,764 |
| Sterile insect technique: Steriles and distribution | 0 | 3,925 | 3,925 | 0 | 3,925 | 3,925 | 0 | 3,925 | 3,925 | 0 | 54,950 |
| Chemical: | | | | | | | | | | | |
| Insecticide and application | 1,267 | 12,537 | 3,169 | 4,345 | 42,984 | 10,862 | 1,361 | 13,462 | 3,401 | 0 | 233,236 |
| Trap surveying | 3,931 | 4,628 | 4,628 | 13,296 | 15,869 | 15,869 | 5,103 | 4,969 | 4,969 | 324 | 183,431 |
| Other control costs | 1,694 | 4,470 | 2,736 | 3,379 | 12,897 | 6,949 | 1,745 | 4,726 | 2,863 | 0 | 102,066 |
| APHIS PPQ officer | 18 | 0 | 0 | 37 | 0 | 0 | 128 | 0 | 0 | 40 | 514 |
| Total program cost | 6,910 | 25,570 | 14,649 | 21,057 | 75,713 | 38,256 | 8,337 | 27,095 | 15,362 | 364 | 576,961 |
| Federal involvement | | | | | | | | | | | |
| Full[a] | 2,073 | 7,671 | 4,395 | 6,317 | 22,714 | 11,477 | 2,501 | 8,129 | 4,609 | 109 | 173,090 |
| Limited[b] | 1,693 | 3,910 | 3,444 | 5,014 | 9,819 | 8,218 | 2,093 | 4,090 | 3,588 | 109 | 103,119 |

[a] 30 percent of total program cost.
[b] 30 percent of all nonchemical program costs.

Table 4-17. **Boll Weevil Suppression Costs With Full Federal Involvement (thousands of dollars)**

| Year | Insecticide and application | Trap surveying | Other control costs | Total program cost | Federal cost[a] |
|---|---|---|---|---|---|
| 1992 | 14,336 | 6,889 | 8,307 | 29,532 | 8,860 |
| 1993 | 19,972 | 6,889 | 8,307 | 35,168 | 10,550 |
| 1994 | 14,336 | 6,889 | 8,307 | 29,532 | 8,860 |
| 1995 | 17,474 | 9,751 | 12,928 | 40,153 | 12,046 |
| 1996 | 28,269 | 9,751 | 12,928 | 50,948 | 15,284 |
| 1997 | 20,292 | 9,751 | 12,928 | 42,971 | 12,891 |
| 1998 | 42,665 | 18,357 | 22,807 | 83,829 | 25,149 |
| 1999 | 47,581 | 18,357 | 22,807 | 88,745 | 26,624 |
| 2000 | 35,382 | 18,357 | 22,807 | 76,546 | 22,964 |
| 2001 | 69,470 | 31,242 | 35,605 | 136,317 | 40,895 |
| 2002 | 82,595 | 31,242 | 35,605 | 149,442 | 44,833 |
| 2003 | 69,479 | 31,242 | 35,605 | 136,326 | 40,898 |
| 2004 | 98,871 | 45,537 | 49,694 | 194,102 | 58,231 |
| 2005 | 114,179 | 45,537 | 49,694 | 209,410 | 62,823 |
| 2006 | 99,217 | 45,537 | 49,694 | 194,448 | 58,334 |
| 2007 | 109,223 | 46,848 | 51,894 | 207,965 | 62,390 |
| 2008 | 114,721 | 46,848 | 51,894 | 213,463 | 64,039 |
| 2009 | 101,599 | 46,848 | 51,894 | 200,341 | 60,102 |
| 2010 | 124,258 | 50,638 | 56,364 | 231,260 | 69,378 |
| 2011 | 114,004 | 50,638 | 56,364 | 221,006 | 66,302 |
| 2012 | 117,110 | 50,638 | 56,364 | 224,112 | 67,234 |
| 2013 | 143,590 | 61,466 | 67,278 | 272,334 | 81,700 |
| 2014 | 143,978 | 61,466 | 67,278 | 272,722 | 81,817 |
| 2015 | 146,791 | 61,466 | 67,278 | 275,535 | 82,661 |
| 2016 | 140,575 | 65,535 | 72,004 | 278,114 | 83,434 |
| 2017 | 160,299 | 65,535 | 72,004 | 297,838 | 89,351 |
| 2018 | 152,058 | 65,535 | 72,004 | 289,597 | 86,879 |
| 2019 | 157,185 | 68,613 | 75,822 | 301,620 | 90,486 |
| 2020 | 167,510 | 68,613 | 75,822 | 311,945 | 93,582 |
| 2021 | 146,979 | 68,613 | 75,822 | 291,414 | 87,424 |
| **Total** | 2,813,998 | 1,214,628 | 1,358,109 | 5,386,735 | 1,616,021 |

[a] 30 percent of total program cost.

**Table 4-18. Boll Weevil Suppression Costs With Limited Federal Involvement (thousands of dollars)**

| Year | Insecticide and application | Trap surveying | Other control costs | Total program cost | Federal cost[a] |
|---|---|---|---|---|---|
| 1992 | 14,336 | 6,889 | 8,307 | 29,532 | 8,860 |
| 1993 | 19,972 | 6,889 | 8,307 | 35,168 | 10,550 |
| 1994 | 14,336 | 6,889 | 8,307 | 29,532 | 8,860 |
| 1995 | 5,956 | 2,862 | 4,621 | 13,439 | 4,032 |
| 1996 | 8,297 | 2,862 | 4,621 | 15,780 | 4,734 |
| 1997 | 5,956 | 2,862 | 4,621 | 13,439 | 4,032 |
| 1998 | 17,908 | 8,606 | 9,879 | 36,393 | 10,918 |
| 1999 | 24,948 | 8,606 | 9,879 | 43,433 | 13,030 |
| 2000 | 17,908 | 8,606 | 9,879 | 36,393 | 10,918 |
| 2001 | 26,814 | 12,885 | 12,798 | 52,497 | 15,749 |
| 2002 | 37,355 | 12,885 | 12,798 | 63,038 | 18,911 |
| 2003 | 26,814 | 12,885 | 12,798 | 52,497 | 15,749 |
| 2004 | 29,747 | 14,295 | 14,089 | 58,131 | 17,439 |
| 2005 | 41,442 | 14,295 | 14,089 | 69,826 | 20,948 |
| 2006 | 29,747 | 14,295 | 14,089 | 58,131 | 17,439 |
| 2007 | 2,728 | 1,311 | 2,200 | 6,239 | 1,872 |
| 2008 | 3,800 | 1,311 | 2,200 | 7,311 | 2,193 |
| 2009 | 2,728 | 1,311 | 2,200 | 6,239 | 1,872 |
| 2010 | 7,887 | 3,790 | 4,470 | 16,147 | 4,844 |
| 2011 | 10,987 | 3,790 | 4,470 | 19,247 | 5,774 |
| 2012 | 7,887 | 3,790 | 4,470 | 16,147 | 4,844 |
| 2013 | 22,533 | 10,828 | 10,914 | 44,275 | 13,283 |
| 2014 | 31,392 | 10,828 | 10,914 | 53,134 | 15,940 |
| 2015 | 22,533 | 10,828 | 10,914 | 44,275 | 13,283 |
| 2016 | 8,468 | 4,069 | 4,726 | 17,263 | 5,179 |
| 2017 | 11,797 | 4,069 | 4,726 | 20,592 | 6,178 |
| 2018 | 8,468 | 4,069 | 4,726 | 17,263 | 5,179 |
| 2019 | 6,404 | 3,078 | 3,818 | 13,300 | 3,990 |
| 2020 | 8,922 | 3,078 | 3,818 | 15,818 | 4,745 |
| 2021 | 6,404 | 3,078 | 3,818 | 13,300 | 3,990 |
| **Total** | 484,474 | 205,839 | 227,466 | 917,779 | 275,335 |

[a] 30 percent of total program cost.

program. That program has increased cotton yields (69 pounds, or $34, per acre) and land values ($14 per acre), as farmers switched from less profitable crops, and lowered pesticide costs ($30 per acre savings) by eliminating the need to treat for boll weevils. The magnitude of the beltwide program's results will not necessarily be identical because the program's outcome depends to a large extent on weevil densities and weather (particularly winter temperatures). Some areas of northern Georgia, Alabama, and Mississippi may have weevil conditions similar to the North and South Carolina piedmont, where pesticide savings were approximately $7 and $25 per acre, respectively. (Carlson et al., 1989).

### Impacts on the Bee Industry

Three of the insecticides proposed in the chemical control alternative (malathion, azinphos-methyl, and methyl parathion) are highly toxic to honey bees. Individual producers can face major losses if the notification required by the operational procedures is not followed. APHIS is committed to notifying the public and registered apiarists within the States.

## Cumulative Effects

According to the CEQ regulations (40 CFR 1508.7), "cumulative impact" is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of the agency (Federal or non-Federal) or person that undertakes such actions. Cumulative impact can result from individually minor but collectively significant actions taking place over a period of time.

### Effects With Nonprogram Activities

Cumulative impacts may result from the impacts of APHIS-cooperative boll weevil control activities on any given land, in conjunction with those of other agencies, groups, or individuals. The area potentially affected by these activities is an estimated 7 million acres in the 13 States that are reported to be infested with boll weevils. Individual growers and large agricultural cooperatives repeatedly use insecticides, including malathion, azinphos-methyl, diflubenzuron, and methyl parathion, on cotton fields. As indicated in the discussion of the cotton arthropod complex, these chemicals are used to control a wide variety of pests, including the boll weevil. Although growers are not expected to treat for boll weevils in addition to scheduled program treatments, growers may use additional applications of program insecticides to control other cotton pests. In some cases, additional treatments may be necessary to control insect populations that were not indirectly suppressed by program treatment for boll weevil control. In other cases, additional treatments may be necessary to control pest populations whose natural predators or parasites were eliminated by program treatments. Cooperative control program treatments may be expected to overlap with at least some of these individually applied treatments, resulting in an increased probability of short-term accumulation of these insecticides.

Also, other pesticides may be used on noncotton crops, such as soybeans, corn, and peanuts, on farmland adjacent to program cotton fields. These chemicals include herbicides and insecticides. Some of

the insecticides used on adjacent farmland may have a remote chance of synergistic effects with program insecticides. The program has no control over nonprogram pesticide use, but if this usage complies with all label restrictions, there should be no significant synergistic or cumulative effects.

Boll weevil control activities are expected to reduce total pesticide loading to the environment in the long term, by eliminating the need for boll weevil treatments. Indirectly, this will also be a positive impact on beneficial insect populations and will in turn reduce the need for the chemical control of other cotton pests.

Although residues are not expected to persist in the environment from year to year, the treatment schedules for persistently infested fields may cause a temporary accumulation of insecticide in a localized area if that area is treated again before the insecticide applied in the previous treatment is totally degraded. There is minimal potential for the boll weevil pesticides to add to or result in groundwater contamination because the insecticides evaluated in this EIS are tightly adsorbed to soil particles and are readily degraded by soil microorganisms. Modeling results have also shown that leaching of these insecticides would be limited.

Cultivated fields are not a natural habitat for most wildlife. Because only cultivated fields will be treated and because operational procedures and mitigation measures will reduce offsite insecticide contamination, it is not expected that even the most frequent application schedule would significantly increase risks to local human and nontarget species populations over those calculated in the risk assessment.

While the insecticides used in the program are not expected to have a lasting effect on water quality, these insecticides could create an overall pesticide burden that could put local streams, rivers, and farm ponds at risk (in addition to other pesticides that growers may use). Farm ponds and the aquatic life they support may be especially adversely affected in the late summer months. High water temperature may greatly influence the potential impacts by increasing the metabolism of aquatic organisms, which in turn increases their food intake and thus their pesticide intake if the food is contaminated.

Ponds are also subject to volume reductions during the summer because increased evaporation rates and decreased precipitation serve to concentrate any nonvolatile, soluble contaminant in the water. The lower volume of water also provides less dilution potential if pesticides from drift, direct spray, or runoff enter the pond.

The risks to humans were evaluated on a chronic basis. Systemic and reproductive risk calculations were based on long-term studies. Estimated cancer risks are those that would occur over the life of a suppression or eradication program. Cumulative risks under an eradication program would be less than those under suppression or no action alternatives because the latter two courses of action do not incorporate

a reduction in treatments over time, nor do they enhance the growers' ability to effectively manage secondary pests.

The use of nonchemical control methods may contribute to impacts that result from normal agricultural practices. Methods that require removal of vegetative cover may increase the erosion potential of cotton fields and increase runoff.

### Effects With Other Federal Programs

Boll weevil control activities will be conducted on private cropland—areas that are not likely to be impacted by other Federal or State pest control programs. Most government control programs are aimed at controlling pests on Federal or State lands. The only APHIS-funded program conducted in the areas where boll weevil control activities are likely to occur are grasshopper control treatments in Texas and Arizona, carbaryl, malathion, and acephate are used. In 1985, approximately 46,000 acres of private rangeland in Texas required treatment for grasshopper control. However, in Arizona in 1985, no private acreage was treated. Malathion treatments for grasshoppers are generally applied at midseason, and only to rangeland. Most malathion treatments for boll weevil control in Texas would be applied in early spring or late fall and only to cotton fields; thus, short-term cumulative impacts are not expected.

There is an Imported Fire Ant Regulatory Program; however, no cumulative impacts are expected because it is regulatory in nature, as opposed to an active control program. This program recommends using hydramethylnon and fenoxycarb (in the form of bait on corn cob grit), diazinon or chlorpyrifos as a drench on nursery stock, and chlorpyrifos on sod farms to kill imported fire ants before shipping the sod to unregulated areas. However, diazinon and chlorpyrifos are organophosphate insecticides. If a sod farm or nursery were adjacent to cotton fields and the treatments coincided or were done within a short period of one another, workers may experience acetylcholinesterase inhibition.

The National Boll Weevil Cooperative Control Program may potentially cause increases in cotton production and decreases in production costs beltwide. Widespread increases in cotton acreage planted and cotton yields may have impacts on cotton prices and USDA cotton programs, such as price supports and payments-in-kind. Additional cotton production may also have an impact on competing goods, such as wool, synthetic fabrics, and other oilseeds.

### Synergistic Effects

There is a possibility that an insecticide applied during boll weevil control operations may interact with other chemicals applied for other purposes and cause synergistic effects. Such effects occur when the combined toxic effects of two or more chemicals cannot be predicted based on the known toxic effects of the individual chemicals, or when the combined effect is greater than the sum of the effects of each insecticide. For example, when each is administered alone at a given dose, chemical A causes 20 percent cholinesterase inhibition and chemical B causes 10 percent inhibition. In the usual case, when the two doses are

administered at the same time, an additive effect would be observed, resulting in 30 percent cholinesterase inhibition. However, if the two chemicals have a synergistic interaction, cholinesterase inhibition of greater than 30 percent would be observed.

Cotton crops are heavily treated with pesticides. More than 30 insecticides are registered for use on cotton. Table 4-19 summarizes the insecticides used on cotton and lists the pests they control. Considering the large number of pesticides applied to cotton, relatively little data are available about the effects of the proposed boll weevil control insecticides in combination with other chemicals. Available information is described below.

### Malathion

A synergistic effect of malathion and its basic hydrolysis products was found in the fathead minnow (Bender, 1969). Although this could cause concern with respect to multiple applications within the same season, mitigation measures to protect bodies of water should reduce the chance of this effect occurring.

Malathion is one of the insecticides most often identified as a member of a synergistic pair of chemicals, many of which are registered for use on cotton crops. The combinations of malathion and phosphonothioic acid (EPN) or malathion and trichlorfon were found to be synergistic in their effects on Japanese quail and ring-necked pheasant chicks (Kreitzer and Spann, 1974). The combination of malathion and EPN also leads to increased toxicity in dogs (Karczmar et al., 1962). Malathion and carbaryl were synergistic in rats (Abdel-Rahman et al., 1985). The combinations of malathion, chlordane, and parathion (Keplinger and Deichmann, 1967) and malathion and disulfoton (Costa and Murphy, 1983) were synergistic in mice at acute toxic levels. Malathion has also been found to be synergistic with ruelene, phosalone, Abate®, baycarb, and possibly methoxychlor (NLM, 1988). The toxicity of malathion given to mice with sublethal doses of parathion, methyl parathion, or fenitrothion indicated that all were substantial potentiators of malathion toxicity (Ramakrishna and Ramachandran, 1978). Of these known synergists with malathion, carbaryl, disulfoton, EPN, parathion, and trichlorfon are used for cotton pest control.

### Azinphos-methyl

According to Berisford et al. (1985), the combination of azinphos-methyl and trichlorfon is synergistic. NLM (1988) reports that mixtures of azinphos-methyl with synthetic pyrethroids are synergistic. Pyrethroids used for cotton pest control include cypermethrin, fenvalerate, flucythrinate, permethrin, and tralomethrin.

### Diflubenzuron

Diflubenzuron is synergistic with the defoliant DEF, which is commonly used on cotton (NLM, 1988). However, cotton is only defoliated at

**Table 4-19. Common Cotton Insect Pests and Chemical Controls**

| Insect | Insecticides used for control |
|---|---|
| Beet armyworm (*Spodoptera exigua* (Hübner)) | Acephate, methidathion, methomyl, methyl parathion, sulprofos, trichlorfon, diflubenzuron, thiodicarb |
| Boll weevil (*Anthonomus grandis* (Boheman)) | Aldicarb, azinphos-methyl, carbaryl, chlorpyrifos, diflubenzuron, EPN, EPN + methyl parathion, EPN + methyl parathion + chlorpyrifos, fenvalerate, malathion, methomyl, methomyl + methyl parathion, parathion, permethrin |
| Bollworm (*Heliothis zea* (Boddie)) | Acephate, carbaryl, chlordimeform, fenvalerate, chlorpyrifos, endrin + methyl parathion, EPN, EPN + methyl parathion, EPN + methyl parathion + chlordimeform, EPN + methyl parathion, tralomethrin, cyfluthrin, and bifenthrin |
| Cabbage looper (*Trichoplusia ni* (Hübner)) | Acephate, fenvalerate, methamidophos, methomyl, permethrin |
| Cotton aphid (*Aphis gossypii* (Glover)) | Aldicarb, azinphos-methyl, carbophenothion, chlorpyrifos dimeton, dicrotophos, dimethoate, disulfoton, endosulfan, ethion, malathion, methamidophos, methyl parathion, oxydemeton methyl, parathion (ethyl), phorate |
| Cotton fleahopper (*Pseudatomoscelis siriatus* (Reuter)) | Aldicarb, azinphos-methyl, carbaryl, dicrotophos, dimethoate, malathion, methyl parathion, trichlorfon, phosphamidon |
| Cotton leaf perforator (*Bucculatrix thurberiella* (Busck)) | Methomyl, aldicarb |
| Cotton leafworm (*Alabama argillacea* (Hübner)) | Azinphos-methyl, carbaryl, EPN + methyl parathion, malathion, methyl parathion, parathion (ethyl), diflubenzuron |
| Cutworms (*Agrotis ipsilon* (Hufnagel), *Agrotis malefida* (Guenée), *Peridroma saucia* (Hübner), Feltia subterranea (Fabricius), *Euxoa auxiliaris* (Grote)) | Acephate, carbaryl, chlorpyrifos, sulprofos, trichlorfon |
| Darkling ground beetles (*Blapstinus* spp. and *Ulus* spp.) | Carbaryl |
| Fall armyworm (*Spodoptera frugiperda* (J.E. Smith)) | Acephate, carbaryl, methomyl, methyl parathion, sulprofos, trichlorfon, diflubenzuron |
| Garden webworm (*Achyra rantalis* (Guenée)) | Carbaryl, malathion, methyl parathion |
| Grasshoppers (*Schistocerca americana* (Drury), *Trimerotropis pallidipennis pallidipennis* (Burmeister), *Melanoplus differentialis* (Thomas), *Brachystola magna* (Girard), *Melanoplus sanguinipes* (Fabricius), *Melanoplus femurrubrum* (De Geer), *Melanoplus bivittatus* (Say)) | Carbaryl, malathion, methyl parathion |

**Table 4-19. Common Cotton Insect Pests and Chemical Controls (continued)**

| Insect | Insecticides used for control |
|---|---|
| Lygus bugs (*Lygus hesperus* (Knight), *Neurocolpus nubilus* (Say), *Chlamydatus associatus* (Uhler), *Adelphocoris rapidus* (Say), *Adelphocoris superbus* (Uhler), *Lygus lineolaris* (Palisot de Beauvios)) | Acephate, aldicarb, azinphos-methyl, carbaryl, chlorpyrifos, dicrotophos, dimethoate, malathion, methyl parathion, trichlorfon |
| Pink bollworm (*Pectinophora gossypiella* (Saunders)) | Azinphos-methyl, carbaryl, fenvalerate, permethrin |
| Saltmarsh caterpillar (*Estigmene acrea* (Drury)) | Carbaryl, methyl parathion, trichlorfon |
| Spider mites (*Tetranychus* spp.) | Aldicarb, carbophenothion, chlorpyrifos, demeton, dicofol, dicrotophos, disulfoton, ethion, methamidophos, methidathion, methyl parathion, oxydemetonmethyl, parathion, phorate, propargite, sulfur |
| Stink bugs (Various species) | Carbaryl, endosulfan, methyl parathion, parathion (ethyl), trichlorfon |
| Thrips (*Frankliniella tritici* (Fitch), *Frankliniella exigua* (Hood), *Frankliniella gossypiana* (Hood), *Frankliniella occidentalis* (Pergande), *Thrips tabaci* (Lindeman), *Sericothrips variablis* (Beach) *Frankliniella fusca* (Hinds)) | Azinphos-methyl, carbaryl, dicrotophos, dimethoate, endosulfan, malathion, methamidophos, methyl parathion, parathion, trichlorfon |
| Tobacco budworm (*Heliothis virescens* (Fabricius)) | Parathion + chlorpyrifos, EPN + methyl parathion + methomyl, fenvalerate, flucythrinate, methomyl, methyl parathion, methyl parathion + methomyl, parathion, permethrin, permethrin + chlordimeform, profenofos, sulprofos, tralomethrin, cyfluthrin, and bifenthrin |
| White flies (*Trialeurodes abutilonea* (Haldman), *Trialeurodes vaporarium* (Westwood), *Bemisia tabaci* (Gennaduis)) | Acephate, methamidophos, methidathion |
| Yellow-striped armyworm (*Spodoptera* spp.) | Carbaryl, methyl parathion, trichlorfon |

Sources: Adapted from NRC, 1981; USDA, 1983.

the end of the season, while diflubenzuron is used solely for spring treatments.

### Methyl Parathion

The carbamate insecticide Temik® (aldicarb, a cholinesterase inhibitor) was given to mice with methyl parathion at one-half of the $LD_{50}$ values for each. The effect was additive, not synergistic (Dorough, 1970).

## Unavoidable Environmental Effects

Unavoidable environmental effects likely to occur because of the boll weevil program include adverse impacts on nontarget insects, aquatic species, and workers.

The killing of nontarget insect species is unavoidable because all the chemicals proposed for use are broad-spectrum insecticides. The reduction in nontarget insect populations may result in temporary increases in populations of other cotton pests, reduction in available pollinators, and reduction in the prey base for insectivorous species.

Runoff from program fields may have an adverse impact on aquatic habitats. Farm ponds and small streams are likely to be severely affected. Malathion and azinphos-methyl are potentially the most harmful to nearly all aquatic species. Diflubenzuron and methyl parathion are harmful to aquatic invertebrates. Individual invertebrates are likely to be harmed; however, no long-term effects to populations are anticipated.

Workers may suffer from adverse systemic and reproductive effects from boll weevil control program activities. Ground applications of methyl parathion have the greatest potential for human health effects. The standard operating procedures and mitigation measures listed in chapter 2 will reduce these risks significantly.

## Irreversible and Irretrievable Commitment of Resources

The time, labor, and expenses of boll weevil suppression or eradication activities represent an irreversible and irretrievable commitment of government resources. The amount of petroleum products, chemicals, and possibly sterile insects used in boll weevil control activities are additional irreversible and irretrievable resource commitments. From an environmental standpoint, it is not expected that any of the control methods will irreversibly or irretrievably commit resources.

## Short-term Uses Versus Long-term Productivity

The relationship between short-term uses of the environment and the maintenance of long-term productivity depends on site-specific information. The boll weevil suppression and eradication alternatives limit the boll weevil population to varying degrees. This should result in higher cotton yields per acre and thus an increase in long-term productivity.

None of the activities related to boll weevil control are expected to result in long-term effects on soil productivity. The preferred alternative of beltwide eradication allows program cooperators to choose from a full range of control methods based on the boll weevil population

densities and environmental sensitivity of each site. All of the control methods have been used in agriculture with no evidence of impairment of long-term productivity.

## Conflicts With Plans of Federal, State, or Local Agencies

As stated in the operational procedures in table 2-2 in chapter 2, control program personnel must follow all applicable Federal, State, and local environmental laws and regulations. In addition, NEPA implementation regulations require an agency to coordinate with other Federal Agencies that may require separate or additional environmental reviews of a Federal program. Coordination of these reviews can be used to avoid potential conflicts with the plans of other Federal agencies. Applicable environmental regulations and consultation requirements are more fully described in chapter 5.

Cooperation with State and local agencies is critical to the success of cooperative boll weevil control efforts. Before participating in the National Boll Weevil Cooperative Control Program, States must approve legislation mandating grower participation, providing program personnel authority to enter private cropland, providing a mechanism for assessment and collection of grower funds, and providing for cooperation with contiguous States in a uniform control effort. Passage of this legislation depends on the approval of most of the cotton growers, as indicated by grower referenda in specific program States. Failure to enact enabling legislation would preclude the State's involvement in the cooperative program.

Particular State legislation may also incorporate mandatory use of cultural control methods, creation of elimination zones where the planting of cotton is forbidden, and establishment of quarantine areas. Specific State mandates will be incorporated in the control program strategy for particular States. In this manner, conflicts with State control program goals may be avoided.

Control program personnel will also comply with all applicable Federal, State, and local environmental laws and regulations in conducting boll weevil control activities. Specific State and local laws and regulations may include the following:

- State and local noise ordinances that may restrict operating hours of pesticide application equipment and vehicles;

- State and local water quality regulations that may establish restrictive buffers around aquatic habitats;

- State and local pesticide applicator certification requirements; and

- State and local restrictions on pesticide use, including bans on the application of specific chemical insecticides; restriction of spraying operations because of weather conditions; and establishment of buffers around residences, schools, and other human habitats.

Chapter 5 contains additional information about applicable regulations and consultation requirements.

## Energy Requirements

Fuel use in the eradication or suppression of the boll weevil involves the consumption of fuels in the transport of personnel, materials, and equipment to a treatment area. Fuel is also consumed in the operation of aircraft and other equipment during some of the treatments. The principal fuels used are petroleum products such as gasoline, diesel fuel, and aviation fuel.

# Chapter 5

# Applicable Environmental Regulations and Consultation Requirements

## Overview

This chapter describes some of the Federal and State environmental laws that potentially apply to the cooperative control program. Numerous statutes and regulations designed to protect environmental quality have been enacted or issued by the Federal Government, many States, and by some local municipalities. The statutes and rules not only regulate existing activities but also impose review requirements on individuals and government agencies proposing actions that may have an impact on the environment.

The Animal and Plant Health Inspection Service (APHIS) must comply with Federal, State, and local laws designed to protect environmental quality, and the Agency recognizes that site-specific program modifications may be required to ensure compliance. The operational procedures and mitigation measures described in chapter 2 of this programmatic environmental impact statement (EIS) are designed to ensure that all cooperative control activities are conducted in compliance with applicable Federal laws. Site-specific procedures for complying with applicable State and local laws in conducting control operations will be developed before treatment is begun in a specific program increment.

## Environmental Policy Requirements

In 1969 the National Environmental Policy Act (NEPA) (42 U.S.C. 4321 et seq.) established policies and procedures for ensuring that Federal actions are consistent with the Nation's environmental quality objectives. NEPA requires Federal agencies to use a "systematic, interdisciplinary approach" to assess the impact of "major Federal actions significantly affecting the quality of the human environment." Regulations promulgated by the Council on Environmental Quality (CEQ) provide detailed requirements for implementing NEPA (40 CFR 1500-1508). Furthermore, Federal agencies, including the Department of Agriculture, have established their own supplemental implementing procedures, as required by the CEQ regulations (7 CFR l(b)). APHIS guidelines provide further detail for implementing NEPA (44 FR 50318-50384 and 44 FR 51272-51274, August 28, 1979).

Several States also have enacted State environmental policy acts (SEPAs) and have promulgated implementing regulations. These acts require State agencies to assess the impact of major State actions that may significantly affect the environment.

This EIS documents the results of an environmental analysis of the control methods and program alternatives available to program cooperators for controlling boll weevils in the Cotton Belt of the United States. It may be used as a broad, comprehensive background source

from which any necessary subsequent environmental analysis can be tiered, in accordance with CEQ's procedures for implementing NEPA (40 CFR 1502.20 and 1508.28). Tiering eliminates repetitive discussions of the same issues and allows consideration of the actual issues that have triggered the additional environmental analysis.

Future environmental analyses of APHIS-funded boll weevil cooperative control activities that may be conducted at a program increment level will focus on resources that are unique to particular States, as necessary. When necessary, cooperative agreements will be negotiated with each State to prepare any site-specific analysis. However, APHIS is ultimately responsible for their completion and adequacy.

## Endangered and Threatened Species and Critical Habitat Requirements

Federal policies and procedures for protecting endangered and threatened species of fish, wildlife, and plants were established by the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.), and regulations were issued pursuant to the ESA. The objectives of the ESA are to provide mechanisms for conservation of endangered and threatened species and the habitats they depend on and to achieve the goals of international treaties and conventions related to the conservation of fish, wildlife, and plants. Under ESA, the Secretary of the Interior or Commerce is required to determine which species are endangered or threatened and to issue regulations to protect those species.

Section 7 of the ESA requires Federal agencies to consult with the Fish and Wildlife Service (FWS) or the National Marine Fisheries Service (NMFS) to ensure that any action that they authorize, fund, or carry out is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of its critical habitat (16 U.S.C. 1536(a)(2)). In addition, the act requires that if species proposed for listing or critical habitat proposed for designation are likely to be jeopardized, destroyed, or adversely modified, respectively, a conference must be held with FWS or NMFS.

Because of the species involved in the boll weevil program, APHIS consulted with FWS. The FWS has determined that, as of March 1991, 198 threatened, endangered, or proposed species were present within U.S. cotton-producing counties. APHIS has prepared a biological assessment for all States involved in the National Boll Weevil Cooperative Control Program to identify how these species might be affected by control program activities. As part of the biological assessment process, APHIS developed measures to protect these species from potential adverse effects from the treatments. The FWS reviewed these protective measures as a part of their biological opinion. Any modifications to the protection measures requested by FWS were made during the consultation process required by Section 7 of the ESA. Specific biological and distributional data will be gathered through program-level contacts with State and local FWS officials. A summary of the biological assessment can be found in appendix H, "Analysis and Protection of Endangered and Threatened Species."

Federal candidate species (provided by FWS for planning purposes) have no protection under the ESA. As these species are proposed or listed, they will be addressed in an APHIS/FWS ESA Section 7 consultation.

As discussed previously, site-specific environmental assessments will also involve cooperation with State wildlife specialists to evaluate impacts on State-protected species. Appropriate protection measures for these species will be identified in site-specific environmental assessments.

## Fish and Wildlife Conservation Requirements

The Fish and Wildlife Conservation Act of 1980 (16 U.S.C. 2901 et seq.) encourages Federal agencies to conserve and promote conservation of nongame fish and wildlife and their habitats to the maximum extent possible within each agency's statutory responsibilities. (The act also helps States in developing fish and wildlife conservation plans.) The operational procedures and mitigation measures in the proposed boll weevil control program have been designed to minimize adverse impacts on fish and other wildlife. In addition, as described in the section above, APHIS has adopted measures to protect wildlife that is endangered, threatened, or proposed for listing under the endangered species act.

The Migratory Bird Treaty Act, as amended (16 U.S.C. 703-711), prohibits killing, capturing, or transporting protected migratory birds and their nests and eggs. Under this act, consultations with FWS and State agencies are encouraged if project activities could directly or indirectly harm migratory birds.

The monitoring program, which routinely evaluates pesticide levels in soil and water, also tests carcasses of animals found in or near program sites. Should bird or other wildlife mortality results from program activities, consultation with FWS will occur.

## Heritage Conservation Requirements

Many Federal laws and regulations exist to protect the Nation's historic, cultural, and prehistoric resources. These include the National Historic Preservation Act, the Archaeological and Historic Preservation Act, the Archaeological Resources Protection Act, the American Indian Religious Freedom Act, the National Natural Landmarks Program, and the World Heritage List. In addition, most States have established programs designed to protect cultural and archeological resources.

Compliance with Federal requirements for heritage conservation is largely accomplished at the programmatic level. APHIS' activities are unlikely to have any effect on sites contained within the National Register of Historic Places (maintained by the National Park Service). However, before implementing control program activities in a new increment, the National Register will be reviewed and the Advisory Council on Historic Preservation's prescriptions for protection of designated properties will be followed (30 CFR 800.7).

## Wetlands Protection Requirements

Executive Order 11990 requires Federal agencies to minimize the loss or degradation of wetlands while carrying out their responsibilities. Many States, particularly coastal States, also have implemented programs designed to protect wetlands.

None of the cooperative control program activities on private cropland should directly affect any wetlands. If preliminary mapping of cotton fields reveals wetlands in close proximity to fields requiring treatment, APHIS will develop site-specific mitigation. Potential adverse impacts would also be avoided by the operational procedures and mitigation measures described in this EIS and by compliance with all applicable Federal environmental regulations.

## Recreation Resources Requirements

A number of Federal laws have been enacted to protect important national recreational resources, including the National Wild and Scenic Rivers System, established by the Wild and Scenic Rivers Act (16 U.S.C. 1271 et seq.); the National Trails System, established by the National Trails System Act (16 U.S.C. 1241 et seq.); wilderness areas administered by the Forest Service, Bureau of Land Management (BLM), National Park Service, and Fish and Wildlife Service; areas of critical environmental concern administered by BLM; and estuarine sanctuaries designated under the Coastal Zone Management Programs.

In general, these laws include provisions to discourage Federal agencies from taking actions that would impair the recognized values of the recreational resources in question. Most land protected by these laws is owned or managed by Federal or State agencies and would not be directly affected by cooperative control program activities on private cropland. However, some cotton fields may be located close to these recreational resources, and the potential indirect impacts of factors such as pesticide drift or noise must be considered.

The Wild and Scenic Rivers Act restricts Federal agency participation in water projects that would affect designated wild or scenic rivers. Pursuant to the act, a nationwide inventory listed rivers potentially qualified for inclusion in the Wild and Scenic Rivers System. Federal agencies are required to consult with the Department of the Interior or the Department of Agriculture before taking actions that might foreclose wild, scenic, or recreational river status for the inventoried rivers (45 FR 59190, September 8, 1980). Primary emphasis in the administration of wild and scenic rivers is to be given to protecting aesthetic and scenic features, as well as other values (P.L. 90-542, Sec. 10). Mitigation measures will be developed for rivers not listed on the inventory that are adjacent to cotton fields requiring treatment.

Similar regulations protect the scenic and recreational qualities of designated wilderness areas and wilderness study areas (44 FR 720114, December 12, 1979). Chemical treatments are discouraged in these areas unless public health and safety or economic values are at severe risk.

The National Trails System Act discourages Federal activities that limit access opportunities to designated trails or that are incompatible with recreational uses.

Numerous State programs are also designed to enhance and protect recreational resources. Most States administer systems of State parks and State forests, and many also have programs that designate and protect scenic rivers in addition to those in the federally designated system. States may also administer game or wildlife management areas, natural areas, scenic and recreational trails, or other environmentally sensitive areas. States will be asked to help identify these sites as recommended in the mitigation measures.

## Air Quality Requirements

The Clean Air Act Amendments of 1977 (42 U.S.C. 1857 et seq.) establish the basic framework for Federal, State, and local air quality management programs. National Ambient Air Quality Standards are promulgated as primary standards (for the protection of human health) and secondary standards (for the protection of other values such as crops and materials). The principal implementation provision of the Clean Air Act requires each State to develop and implement a plan to achieve the Federal ambient air quality standards within specified time limits. The resulting State Implementation Plans (SIPs) provide the basic regulatory programs for controlling pollutant emissions from existing and future emission sources.

The Clean Air Act Amendments of 1990 (42 U.S.C. 7401 et seq.) strengthen the existing Clean Air Act by creating sanctions for nonattainment of air quality standards and allowing the creation of Federal Implementation Plans (FIPs) for States with inadequate programs. Other aspects of the 1990 amendments include acid rain controls, stricter tail pipe emissions standards, programs for alternative-fueled vehicles, and stratospheric ozone protection.

The Environmental Protection Agency (EPA) has not identified any of the pesticides under consideration in this EIS as hazardous air pollutants to be regulated under Section 112 of the Clean Air Act. Program vehicles will comply with all applicable Federal and State emissions standards.

## Water Quality Requirements

The Clean Water Act (CWA), as amended (33 U.S.C. 1251 et seq.), provides the national strategy for controlling water pollution. The law prescribes national water quality goals and policies, establishes uniform effluent discharge limitations, requires States to establish and enforce water quality standards, establishes various levels of water quality planning, and establishes a National Pollutant Discharge Elimination System permit program for municipal and industrial point-source discharges.

Section 208 of the CWA specifies State-level programs for controlling nonpoint-source pollution. States are required to prepare water quality management plans to achieve the act's goal of fishable and swimmable

waters. In these plans, States must establish regulatory programs to control runoff and other pollution associated with agriculture, forestry, construction, and other nonpoint sources of pollution. Water quality management plans are prepared for specific watersheds and regions of each State and pertain to the conditions and activities present in those watersheds or regions.

Section 303 of the CWA specifies requirements for State water quality standards. Under Section 303 and additional EPA regulations pertaining to water quality standards (40 CFR 120), States are required to establish and enforce water quality standards that protect public health and welfare and downstream water quality. Existing water quality standards are to be upgraded to achieve the CWA's goals of waters suitable for fishing and swimming.

Because boll weevil control activities do not involve point-source discharges of pollutants, the provisions of the CWA pertaining to point-source pollutant discharges would not apply. However, the boll weevil activities would have the potential to cause nonpoint-source discharges. The potential for adverse impacts will be minimized by using the operational procedures and mitigation measures described in this EIS and by complying with all applicable Federal, State, and local regulations and standards concerning water quality, as required by CWA's Section 313(a).

## Groundwater Quality Requirements

The Safe Drinking Water Act (SDWA) (42 U.S.C. 300(f) et seq.) allows EPA to designate any aquifer that serves as the principal source of drinking water for an area as a "sole source" aquifer. Federal agencies are prevented from granting assistance to any project that may contaminate such an aquifer and thus create a significant health hazard (Section 1424, SDWA). Approximately 55 sole source aquifers have been designated, and approximately 9 others have been proposed for consideration. EPA's Office of Drinking Water maintains information on the location of these aquifers. The analysis described in chapter 4 indicates that none of the program chemicals is likely to leach below the root zone. Thus, it is not likely that the recharge zone of any aquifer, sole source or other, would be contaminated by chemicals used in boll weevil control activities. Chapter 4 also discusses potential impacts to drinking water.

## Noise Control Requirements

The Noise Control Act of 1972 (42 U.S.C. 4901 et seq.) establishes a Federal policy, as well as various programs, for controlling noise that is detrimental to public health and welfare. Section 4(b) of the act requires each Federal agency engaged in noise-emitting activities to comply with Federal, State, and local requirements for control and abatement of environmental noise. Typically, permanent noise sources are regulated more strictly at all levels than temporary noise sources, and industrial sources are regulated more strictly than silvicultural or agricultural activities.

Any noise from cooperative control operations would be temporary and would not have greater impacts than current agricultural spraying operations in the area. Aerial treatments would be avoided in areas containing endangered and threatened species determined to be sensitive to noise, and areas around schools, parks, congested areas, or other sensitive receptors. Plans to fly over congested areas must be submitted to the Federal Aviation Administration's district office with jurisdiction in that area. Although these guidelines are primarily safety motivated, they would serve to limit noise impacts in local towns.

## Pesticide Regulation

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended (7 U.S.C. 136 et seq.), establishes procedures for registering, classifying, and regulating all pesticides. EPA is responsible for implementing FIFRA. Primary enforcement responsibility under FIFRA for use-related violations is assigned to States with approved programs. Before any pesticide may be sold legally, it must be registered by EPA. EPA may classify a pesticide for restricted use if it determines that, without restrictions on use, the pesticide may have unreasonable adverse effects on applicators or the environment. Restricted-use pesticides may be applied only by or under the direct supervision of a certified applicator or in accordance with other restrictions (Section 3(d), FIFRA). Three of the pesticides considered for use in this EIS—azinphos-methyl, methyl parathion, and diflubenzuron—are classified as restricted by EPA. States may also classify pesticides; in some cases, States have classified individual pesticides for restricted use, although EPA has not done so.

Regulations for storing and disposing of pesticide containers and excess amounts of pesticides have also been promulgated by EPA and the States. Disposal procedures for empty insecticide containers are described in table 2-1 in chapter 2.

The operational procedures described in this EIS are designed to satisfy applicable FIFRA requirements. Only EPA-registered insecticides will be used in boll weevil control activities, in strict accordance with EPA-approved and applicable State-approved label instructions. Some of the specific operational procedures listed in table 2-1 (in chapter 2) are derived from label requirements applicable to all four insecticides considered for aerial application. APHIS and its cooperators would be required to comply with all label requirements that may be unique to each insecticide.

Section 408 of the Federal Food, Drug, and Cosmetic Act (FFDCA) authorizes the establishment of tolerance levels of pesticides on food or feed crops. These tolerance levels, set by EPA, are the amounts of pesticide residues that may safely remain on food or feed crops after harvest. The Food and Drug Administration and the Department of Agriculture enforce tolerance levels by inspecting agricultural commodities, meat, and poultry before sale.

As discussed in chapter 4, food crops are often grown adjacent to cotton fields. The insecticides under consideration for the program are broadly registered for most crops likely to be included in a treatment area.

## State Environmental Regulations

Most States impose additional regulations on pesticide applications. These regulations are designed to provide mitigation of State-specific impacts or to reflect the residents' unique environmental objectives. This section summarizes State regulations that are potentially applicable to cooperative control program operations. An ongoing review of the State regulations will ensure compliance with State guidelines.

The Cotton Belt States of Alabama, Arkansas, Georgia, Kansas, Louisiana, Mississippi, Missouri, New Mexico, Oklahoma, South Carolina, Tennessee, Texas, and Virginia do not impose additional restrictions on the use of azinphos-methyl, malathion, diflubenzuron, or methyl parathion. The federally registered label for each of these insecticides addresses all facets of use, including the certification of applicators, aerial- and ground-based application methods, worker protection provisions, consultation with appropriate State agencies, and the observance of any required buffer zones around ecologically sensitive areas or areas of human habitation.

Arizona imposes restrictions on the application of azinphos-methyl and methyl parathion in addition to Federal requirements. Buffer zones of one-quarter mile or more must be established around schools and day care centers for both ground-based and aerial-application procedures; health care facilities must be protected with 400-foot buffers. Also, in residential areas, buffer zones of 50 to 300 feet must be designated for azinphos-methyl and methyl parathion applications.

Aerial application of pesticides in North Carolina must include the establishment of buffer zones for residences, schools, and hospitals. No pesticide may be deposited within 100 feet of a residence or within 300 feet of schools, hospitals, or any other type of nonresidential building. In addition, the right-of-way for roads or a 25-foot buffer on each side of a road must be protected from pesticide deposition.

Although the State of California does not directly impose buffer zone restrictions on the application of restricted-use pesticides, its counties are empowered to establish buffers they deem necessary. California's pesticide evaluation process is a complex, county-by-county review of a pesticide's human health effects and its potential impact on the specific ecological and economic elements of the given area. Thus, depending on the county, application of the restricted-use pesticides examined in this EIS may or may not require the establishment of buffer zones or other safeguards more stringent than the federally mandated guidelines.

Florida reserves the right to impose buffer zone requirements. However, buffer zones have not yet been established for azinphos-methyl, malathion, diflubenzuron, or methyl parathion.

# Chapter 6

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# Glossary

## A

**Absorption**. The taking up of liquids by solids or the passage of a substance into the tissues of an organism as the result of several processes; that is, diffusion, filtration, or osmosis.

**Acaricide**. A pesticide that kills mites and ticks.

**Acceptable daily intake (ADI)**. The maximum amount of a substance (usually restricted to chemicals) that can be ingested daily by humans, for a lifetime, without causing appreciable adverse effects.

**Acetylcholine (ACh)**. A naturally occurring chemical in organisms necessary for the transmission of nerve impulses across the junctions of nerve fibers by the innervation of contiguous fibers.

**Acetylcholinesterase (AChE)**. A naturally occurring enzyme in organisms produced at the junction of nerve fibers that serves to hydrolyze (split) acetylcholine, thereby ending the transmission of the nerve impulse.

**ACh**. See *acetylcholine.*

**AChE**. See *acetylcholinesterase.*

**Activation**. Use of an enzyme system to enhance or promote the ability of a substance to cause mutations.

**Active ingredient (a.i.)**. The effective part of a pesticide formulation or the actual amount of the technical material present in the formulation.

**Acute**. Having a duration of a few days or less.

**Adenoma**. A glandular tumor.

**ADI**. See *acceptable daily intake.*

**Adsorption**. Adhesion of substances to the surfaces of solids or liquids. Technically, the attraction of ions of compounds to the surfaces of solids or liquids.

**a.i.** See *active ingredient.*

**Alveolar**. Pertaining to blind-ended air sacs of microscopic size found in the lung.

**Ames assay**. A short-term *in vitro* test using bacteria to assess the potential of a substance to cause mutations.

**Amphipod**. Any of a large group of small crustaceans with laterally compressed bodies, commonly called scuds.

**Arthropod**. Members of the phylum Arthropoda include the insects, the crustacea (crabs, lobsters, and shrimp), the arachnids (spiders, ticks, and scorpions), the millipedes, and the centipedes. The arthropod is characterized by a rigid external body covering called a cuticle or exoskeleton; a segmented body; and paired, jointed appendages with at least one pair of functional jaws.

**Assay**. A test or measurement used to evaluate a characteristic of a chemical. See *bioassay*.

**Ataxia**. Inability to coordinate voluntary muscle movements.

## B

**Bioaccumulation**. The process of a plant or animal taking in or storing a persistent substance. Over a period of time, a higher concentration of the substance is found in the organism than in the organism's environment.

**Bioassay**. A way to evaluate chemical levels or concentrations in organisms by studying the responses of treated animals, plants, fungi, or microorganisms under controlled conditions.

**Boll**. The rounded seed pod or capsule of the cotton plant. The cotton lint develops within the enclosed boll.

**Boom**. The long, tubular pipe in a pesticide spray system that serves to distribute the pesticide from a pressurized supply line to a series of spray nozzles mounted along the pipe.

## C

**Cancer potency**. The increase in likelihood of getting cancer from a unit increase (mg/kg/day) in the dose of the chemical.

**Carcinogen**. A substance that causes cancer.

**Cation**. A positively charged ion; the ion in an electrolyzed solution that migrates to the cathode.

**ChE**. See *cholinesterase*.

**Chemical degradation**. The breakdown of a chemical substance into simpler components through chemical reactions.

**Chitin**. A substance that forms the principal component of insect exoskeletons, crustacean shells, and the cell walls of certain types of fungi.

**Cholinesterase (ChE).** A chemical (enzyme) that facilitates the breakdown of other chemicals (choline esters) into simpler products; for example, acetylcholinesterase helps break down acetylcholine into acetic acid and choline.

**Chromosomal aberration.** A structural change in a chromosome, including deletions, duplications, translocations, and changes in the number of chromosomes.

**Chronic.** Lasting more than 3 months.

**Class I area.** Areas of the United States (primarily national parks and wilderness areas) where ambient air concentrations of sulfur dioxide and particulate matter are allowed to be increased only minimally. Strict visibility standards are also in effect around most Class I areas.

**Climax.** The last of a series of successional plant communities (each dominated by different species of plants), which will perpetuate under the prevailing natural environmental conditions.

**Cortical.** Referring to the outer layer of an organ.

**Critical habitat.** Specific areas that may be inside and outside the geographical area occupied by a species that are essential for the preservation of an endangered or threatened species and that have been designated as "critical habitat" in accordance with the Endangered Species Act, section 4.

**Cyanosis.** A bluish discoloration of the skin resulting from lack of oxygen.

**Cytogenetic.** Referring to the development of cells.

## D

**DNA.** Deoxyribonucleic acid. The nucleic acid that is the molecular basis of heredity in many organisms.

**Degradation.** See *chemical degradation* and *microbial degradation.*

**Demyelination.** The destruction or removal of the fatty white material (myelin) surrounding nerve tissue that normally serves to sheath and insulate neurons and their electrical impulses.

**Dermal.** Pertaining to the skin.

**Dermatitis.** Inflammation of the skin caused by an outside agent.

**Desorption.** The removal of ions or compounds attached to the surfaces of particles of soil or organic matter.

**Developmental effect**. A malformation of an embryo or developing fetus resulting from exposure to a toxic substance between conception and birth.

**Diapause**. A morphological or physiological state of dormancy in adult insects; a survival technique that allows the insect to withstand environmental stress, particularly adverse weather conditions such as drought and low ambient temperatures.

**Diptera**. The taxonomic order of the class Insecta containing true flies, mosquitoes, midges, and the like. Dipterans are characterized by having only one pair of functional wings and a second much reduced, nonfunctional pair called halters.

**Dominant lethal test**. A test, usually in rodents, to demonstrate toxic effects on germ cells in the intact male animal.

**Dose**. The amount of a substance that is taken into the body.

**Drift**. That portion of a sprayed substance that moves off the target site.

**Dry weight**. See *oven-dry weight*.

**Dyspnea**. Labored or difficult breathing.

## E

**$EC_{50}$**. Median effective concentration. The concentration (ppm or ppb) of the toxicant in the environment (usually water) that produces a designated effect (usually immobilization) on 50 percent of the test organisms exposed. This is used primarily for microorganisms for which it is difficult or impossible to determine if individual organisms are alive or dead.

**Economic threshold**. That pest population level at which economic damage to the crop begins to occur.

**Edaphic**. Pertaining to the soil or influenced by the soil.

**Edema**. An excessive accumulation of fluid in the cells, tissue spaces, or body cavities resulting from a disturbance in the fluid exchange mechanism.

**EEC**. See *estimated environmental concentration.*

**Endangered species**. Those plant or animal species identified by the Secretary of the Interior or Secretary of Commerce as being in danger of extinction throughout all or a significant portion of their range and listed as "endangered" in accordance with the Endangered Species Act of 1973.

**Environmental analysis**. A procedure defined by the National Environmental Policy Act of 1969, whereby the environmental impacts of a planned action (in this case boll weevil control programs) are objectively reviewed.

**Epidemiology**. Studies of human populations for patterns of illness.

**Eradication**. The removal of a species from an area to the point where individuals of that species are no longer detectable.

**Erythrocyte**. Red blood cell.

**Ester**. An oily substance, usually having a pleasant aroma, whose molecular structure can be represented by RCOOR′, where C is a carbon atom, each O is an oxygen atom, and R and R′ represent the other parts of the molecule that distinguish one ester from another.

**Esterase**. An enzyme that helps split esters into simpler chemical compounds.

**Estimated environmental concentration (EEC)**. Estimated amount of insecticide residue that will be in the environment and available to the organism.

**Exposure**. The amount of insecticide that an organism receives or comes into immediate contact with in its environment.

**Exposure analysis**. The estimation of the amount of chemicals that organisms receive during or following application of pesticides.

## F

**Fetotoxicity**. Direct toxicity to a developing fetus.

**Formulation**. The form in which a pesticide is packaged or prepared for use. A chemical mixture that includes a certain percentage of active ingredient (technical chemical) (with an inert carrier) and other nonreactive chemical ingredients.

## G

**Gastric**. Pertaining to the stomach.

**Gavage**. Feeding by way of a tube inserted into the stomach.

**Granivorous**. Feeding on grains and seeds.

## H

**Half-life**. The time required for a substance (such as an insecticide) in or introduced into a living or nonliving system to be reduced to half of

its original amount whether by excretion, metabolic decomposition, or other natural process.

**Hazard analysis**. The determination of whether a particular chemical is causally linked to particular harmful effects.

**Hematology**. The study of blood.

**Hemoglobin**. The protein in vertebrate red blood cells that carries oxygen to tissues.

**Herbivore**. An animal that feeds exclusively on plants.

**Hiboy**. Tractor-mounted, boom-type ground application equipment capable of treating an entire field; use is limited by soil moisture and size and maturity of crops.

**Histology**. The study of plant and animal tissues.

**Horizons (soil)**. A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil-forming processes.

**Hydrolysis**. A process in which the cleavage of a molecule is accompanied by the addition of a water molecule.

**Hymenoptera**. A large order of insects composed of the ants, bees, sawflies, and wasps. The typical adult has four membranous wings and chewing-type mouthparts.

## I

**Inert ingredients**. In a pesticide formulation, all substances with the exception of the active ingredient.

**Insecticide**. Any substance used to kill insects.

**Insectivorous**. Insect-eating; in common usage, includes animals that eat insects and sometimes other selected invertebrates.

**Instar**. The term for an insect before each of the moults (shedding of its skin) it must go through in order to increase in size. Upon hatching from its egg, the insect is in instar I and is so called until it moults, when it begins instar II, and so forth.

**Intraperitoneal**. Within the peritoneum (a membranous lining of the body cavity).

**Intravenous**. Within a vein.

***In vitro***. A test occurring in an artificial environment, outside a living organism, such as in a test tube or Petri dish.

***In vivo*.** A test occurring within a living organism.

**Isopod.** Any of a large order (Isopoda) of small crustaceans with the body composed of seven free thoracic sections, each bearing a pair of similar legs. Includes the sowbugs.

## L

**$LC_{50}$.** Median lethal concentration. A concentration of a substance in water or air, expressed in milligrams per liter (mg/L) or milligrams per cubic meter ($mg/m^3$), at which 50 percent of the test animals will be killed.

**$LD_{50}$.** Median lethal dose. The dosage of toxicant, expressed in milligrams of toxicant per kilogram of body weight (mg/kg), required to kill 50 percent of the animals in a test population.

**LEL.** See *lowest effect level.*

**Lactation.** The production of milk by a mammal for her offspring.

**Leach.** Usually refers to the transport of chemicals through soil by water; may also refer to the movement of pesticides out of leaves, stems, or roots into the air or soil.

**Lepidoptera.** A large order of insects, including the butterflies and moths, characterized by four scale-covered wings and coiled, sucking mouthparts.

**Lowest effect level (LEL).** The lowest dose level at which toxic effects are observed.

## M

**Margin of safety.** An arbitrary separation between the highest no-effect level of a chemical found by animal experimentation and the level of exposure estimated to be safe for humans.

**Metabolite.** A substance formed by the degradation or biosynthesis of a compound.

**Methemoglobin.** An organic compound formed by oxidation of hemoglobin by toxic substances.

**mg/kg.** Milligrams per kilogram. In this EIS, it usually refers to milligrams of insecticide per kilogram body weight.
1 mg = 0.000035 ounce. 1 kg = 2.2 pounds.

**mg/kg/day.** Milligrams per kilogram of body weight per day.

**mg/L.** Milligrams per liter.

**Microbial degradation**. The breakdown of a chemical substance into simpler components by bacteria or fungi.

**Microcrustacean**. An organism of the class Crustacea that is too small to be seen clearly without magnification.

**Microgram (µg)**. One millionth of a gram.

**Micromole (µmol)**. One millionth of a mole.

**Micron**. A unit of length equal to one millionth ($10^{-6}$) of a meter.

**Microsporidian**. Any protozoan of the order Microsporida, an order of parasitic protozoa found mostly in invertebrates and lower vertebrates.

**Millimole (mmol)**. One thousandth of a mole.

**Mist blower**. Truck-mounted, ground application equipment capable of applying pesticides in a directed mist; in this EIS, around the perimeter of cotton fields.

**Mole**. The amount of a substance that has a weight in grams numerically equal to the molecular weight of the substance.

**Mutagen**. A substance that tends to increase the frequency or extent of genetic mutations (changes in hereditary material).

## N

**Necrosis**. The death of some or all of the cells in an organ or tissue, caused by disease, physical or chemical injury, or interference with the blood supply.

**Neoplasm**. An abnormal growth or tumor.

**Neuropathy**. Any disease or abnormality of the nervous system.

**Neurotoxic**. A compound that is toxic to nerve cells.

**Neurotoxin**. Pertaining to any substance that is poisonous to the nervous system.

**NOEL**. See *no-observed-effect level.*

**Nontarget**. Pertaining to any area or organism that is not the intended object of a particular control method.

**No-observed-effect level (NOEL)**. In a toxicity test, the highest dose at which no adverse effects were observed in the test animals.

## O

**Omnivorous.** Eating both animal and vegetable substances.

**Oncogenic.** Capable of producing or inducing tumors, either benign (noncancerous) or malignant (cancerous), in animals.

**Ossification.** The natural process of bone formation.

**Oven-dry weight.** The weight of a substance after it has been dried in an oven at 105°C to constant weight.

## P

**Parenteral.** Administered by any way other than through the mouth.

**Parts per billion (ppb).** A unit for measuring the concentration of a substance (such as a pesticide) in a medium (such as food or water). For example, if the concentration is 1 ppb, the weight of the substance is 1 billionth the weight of the medium; thus, 1 ppb is equal to 1 microgram of substance per kilogram of food. It is also equal to 1 microgram of substance per liter of water.

**Parts per million (ppm).** A unit for measuring the concentration of a substance (such as a pesticide) in a medium (such as food or water). For example, if the concentration is 1 ppm, the weight of the substance is 1 millionth the weight of the medium; thus, 1 ppm is equal to 1 milligram of substance per kilogram of food. It is also equal to 1 milligram of substance per liter of water.

**Percolation.** The flow of a liquid through a porous substance.

**Pesticide.** Any substance or mixture of substances used in controlling insects, rodents, fungi, weeds, or other forms of plant or animal life that are considered to be pests.

**Phenology.** The study of the relationship between climatic conditions and periodic biological phenomena (such as boll weevil outbreaks). Phenology models rely on this relationship, based on weather and biological data collected in the past, to predict recurrence of such phenomena.

**Pheromone.** A chemical substance released by an animal that influences behavior or development of members of that same species.

**Photochemically reactive.** A property of substances or particles the structures of which may be changed when solar energy is absorbed.

**Photodecomposition.** The breakdown of a substance into simpler components by the action of light.

**Phytotoxic**. Poisonous or harmful to plants.

**Pinhead-square**. A cotton flower bud approximately the size of a pencil eraser. The pinhead-square stage of cotton plant development is also characterized by the presence of eight true leaves on the cotton seedling.

**Piscivorous**. Habitually feeding on fish.

**Platelets**. Cells in the blood of vertebrates that promote clotting.

**Potentiation**. The process by which a substance that had no or minimal adverse effects is made more toxic due to exposure in combination with another substance.

**Protozoa**. A group of microscopic single-celled animals. Most Protozoa are free-living but some are important disease-causing parasites of man.

**Pulmonary**. Pertaining to the lungs.

## Q

**Q-value**. The ratio of the estimated environmental concentration and the median lethal dose of a chemical used by the EPA as a criteria measure of the chemical's toxicity.

## R

**Recombination**. The formation in offspring of genetic combinations different from those in parents.

**Reference dose (RfD)**. The term preferred by the U.S. Environmental Protection Agency to express acceptable daily intake.

**Residue level**. The amount of pesticide that may remain on a crop after harvesting.

**Resorptions**. Absorption by the mother's body of an embryo.

**Respirable particle**. Particle of a size small enough to reach the lungs when inhaled.

**Reverse mutation**. A mutation in which an already mutated cell reverts back to the normal type.

**RfD**. See *reference dose*.

**Riparian area**. Land areas that are directly influenced by water. They usually have visible vegetative and physical characteristics reflecting this water influence. Stream sides, lake borders, or marshes are typical riparian areas.

**Riparian habitat**. Those terrestrial areas where the vegetation complex and microclimatic conditions are products of the combined presence and influence of perennial or intermittent water, associated high water tables, and soils that exhibit some wetness characteristics. Includes riparian zones plus one-half the transition zone (or ecotone) between riparian zones and upland habitat.

**Runoff**. That part of precipitation, as well as any other flow contributions, that washes off the land surface. Water can appear in intermittent or perennial surface streams.

## S

**Safety factor**. A factor conventionally used to extrapolate human tolerances for chemical agents from no-observed-effect levels in animal test data.

**Sensitizer**. A substance that causes increasing levels of dermal irritation upon subsequent applications.

**Serum**. The liquid part of blood, not including formed cells.

**Sister chromatid exchange**. A test that measures the frequency of exchange of segments of chromosome strands.

**Squares**. Cotton flower buds.

**Subacute**. Lasting from a few days to a month.

**Subchronic**. Lasting from 1 to 3 months.

**Surfactant**. A material that improves the emulsifying, dispersing, spreading, wetting, or other surface-modifying properties of liquids.

**Suspended sediment**. Sediment suspended in a fluid by colloidal suspension or by the upward components of turbulent currents.

**Synergism**. A process in which a greater than additive toxicity results from the combined administration of one or more chemicals.

**Systemic toxicity**. Effects produced as a result of the distribution of a poison or foreign substance throughout the body.

## T

**Teratogen**. A substance tending to cause developmental malformations (birth defects) in unborn human or animal offspring. Teratogenicity is the capacity of a substance to cause anatomical, physiological, or behavioral defects in animals exposed during embryonic development.

**Testosterone.** A male sex hormone that controls secondary sex characteristics.

**Threatened species.** Those plant or animal species identified by the Secretary of the Interior or Secretary of Commerce as a species that is likely to become endangered within the foreseeable future throughout all or a significant portion of their range and listed as "threatened" in accordance with the Endangered Species Act of 1973.

**Threshold limit value (TLV).** The concentration of an airborne constituent to which workers may be exposed repeatedly, day by day, without adverse effect.

**Toxicity.** The ability of a substance to cause adverse effects in living organisms.

**Translocation.** The transfer of substances from one location to another in the plant body.

**Turbidity.** An optical property of a liquid that contains suspended particles, causing light to be scattered rather than transmitted through. The suspension liquid typically has a cloudy appearance.

**U**

**Unscheduled DNA synthesis.** A mutagenicity test that indicates DNA repair.

**V**

**Visceral.** Pertaining to internal organs.

**Volatility.** The measure of a substance's ability to evaporate.

**W**

**Wetland or wetland habitat.** Permanently wet or intermittently flooded areas where the water table (fresh, saline, or brackish) is at, near, or above the soil surface for extended intervals; where hydric wet soil conditions are normally exhibited; and where depths generally do not exceed 2 meters.

# INDEX

Chapter numbers precede page numbers (in parentheses)

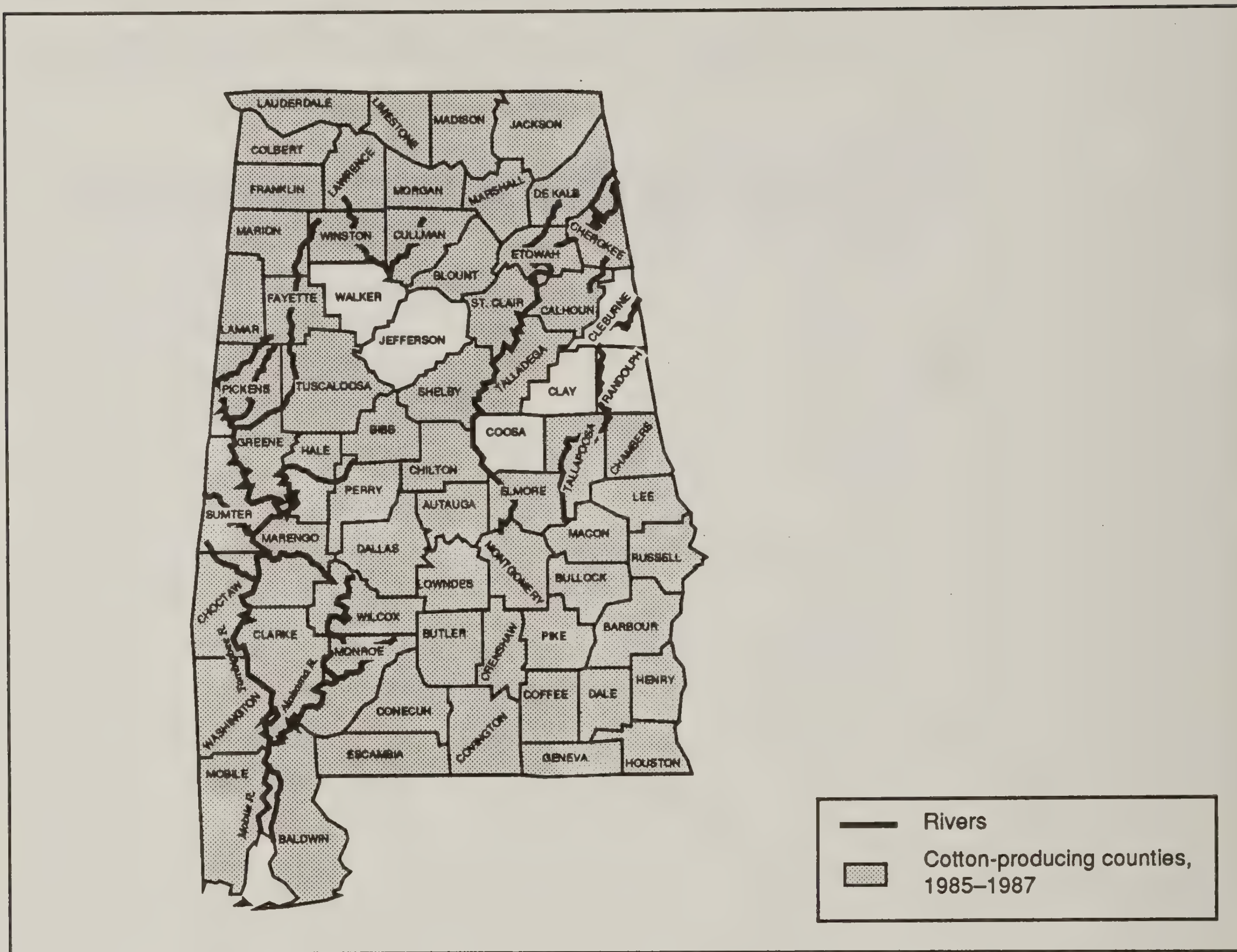
[illegible]

# Appendix A

## Cotton-Producing Counties in the United States

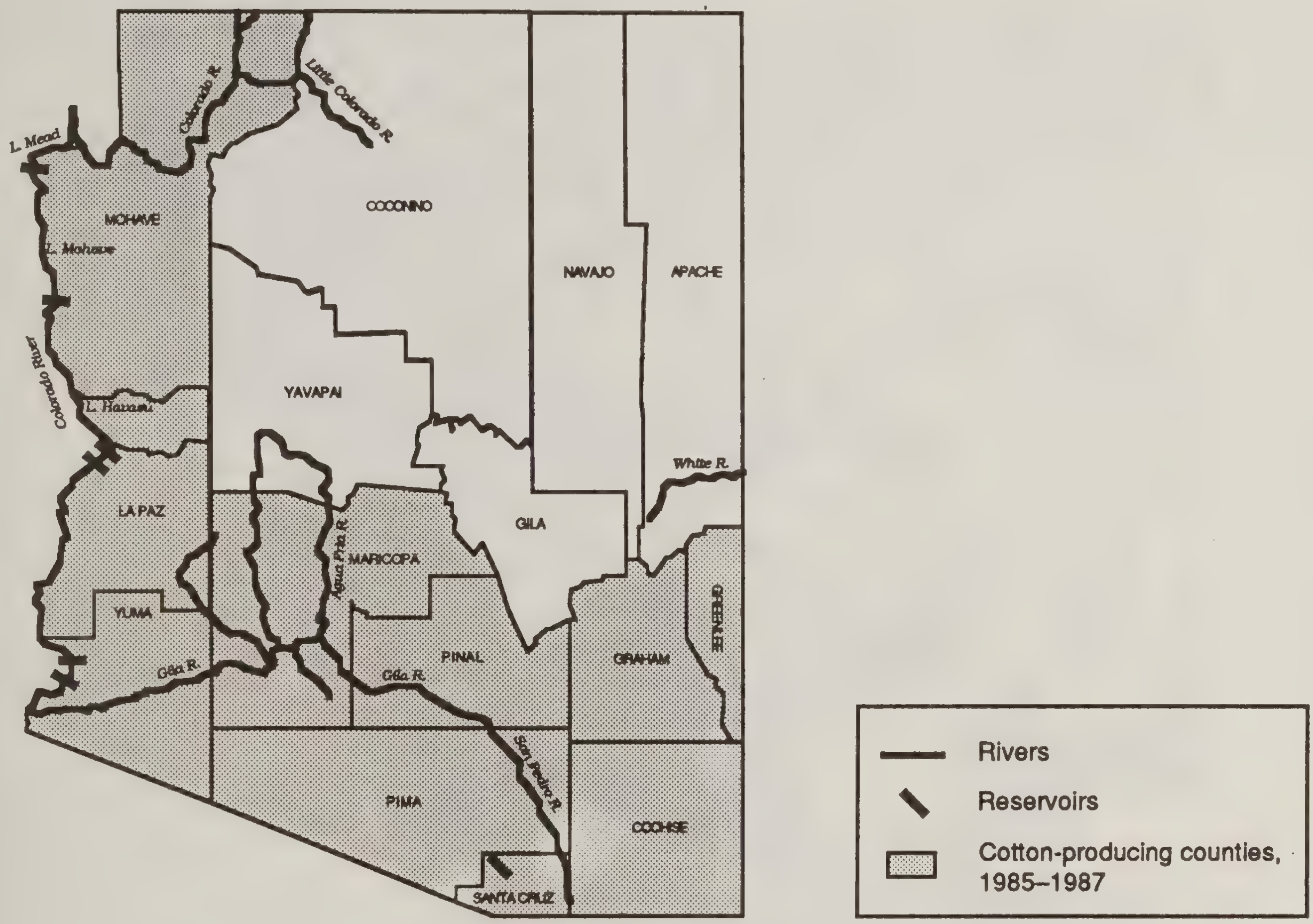
This appendix contains State maps showing counties that produced cotton between 1985 and 1987. Major surface water features are also shown.

## Cotton-Producing Counties in ALABAMA



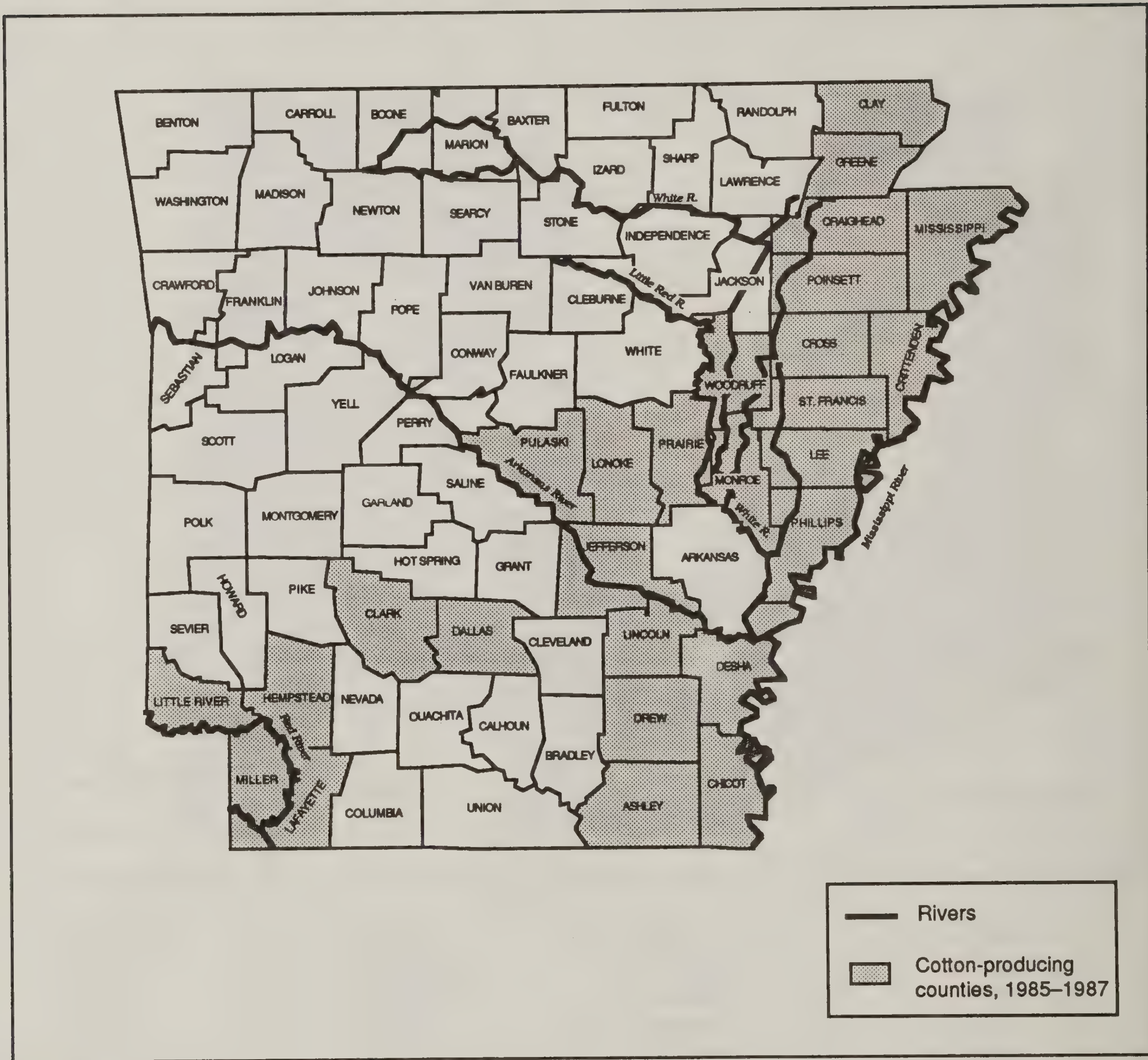

Autauga
Baldwin
Barbour
Bibb
Blount
Bullock
Butler
Calhoun
Chambers
Cherokee
Chilton
Choctaw
Clarke
Coffee
Colbert
Conecuh
Covington
Crenshaw
Cullman
Dale
Dallas
De Kalb
Elmore
Escambia
Etowah
Fayette
Franklin
Geneva
Greene
Hale
Henry
Houston
Jackson
Lamar
Lauderdale
Lawrence
Lee
Limestone
Lowndes
Macon
Madison
Marengo
Marion
Marshall
Mobile
Monroe
Montgomery
Morgan
Perry
Pickens
Pike
Russell
Shelby
St. Clair
Sumter
Talladega
Tallapoosa
Tuscaloosa
Washington
Wilcox
Winston

## Cotton-Producing Counties in ARIZONA



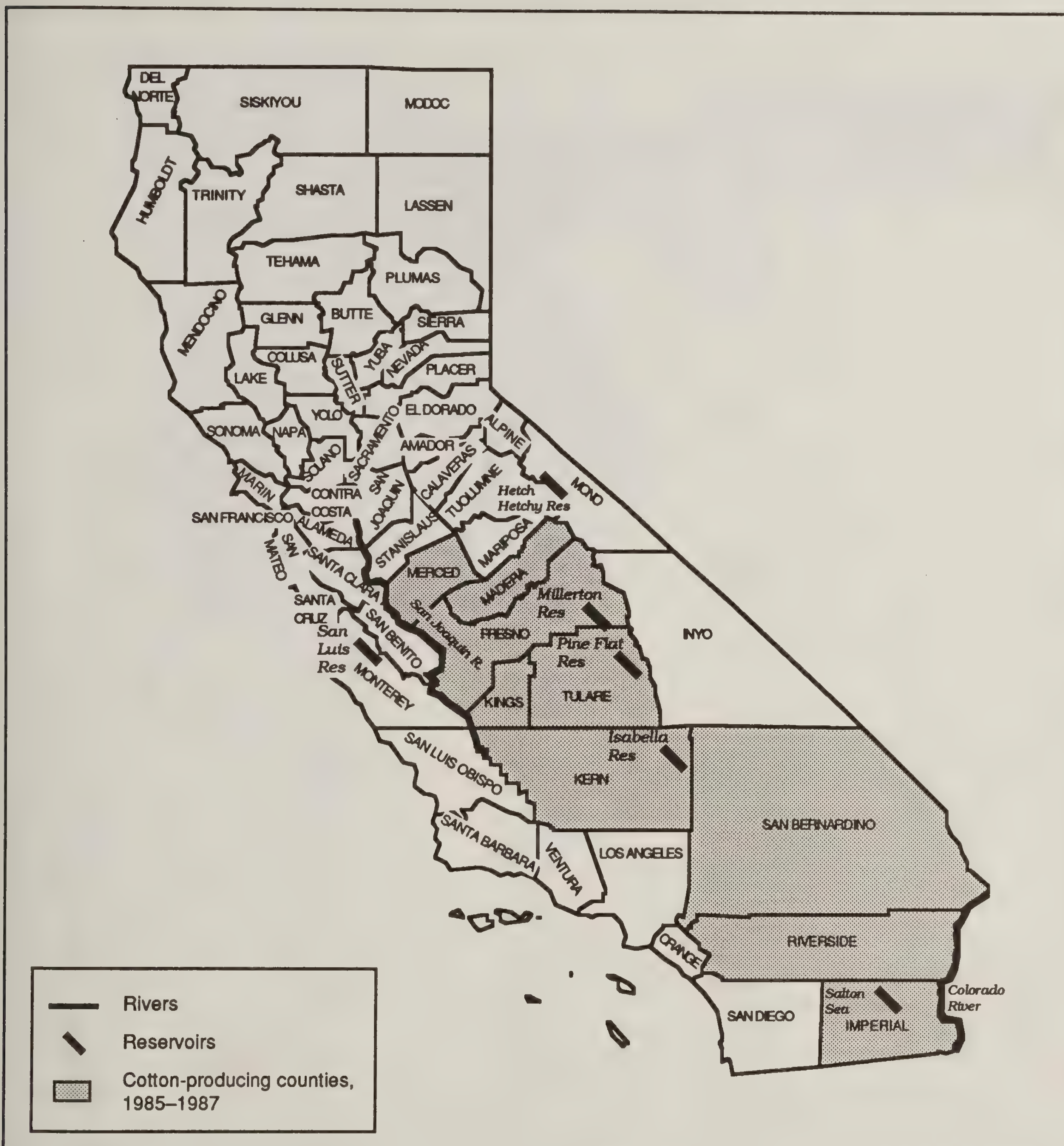

| | | |
|---|---|---|
| Cochise | Maricopa | Santa Cruz |
| Graham | Mohave | Yuma |
| Greenlee | Pima | |
| La Paz | Pinal | |

## Cotton-Producing Counties in ARKANSAS



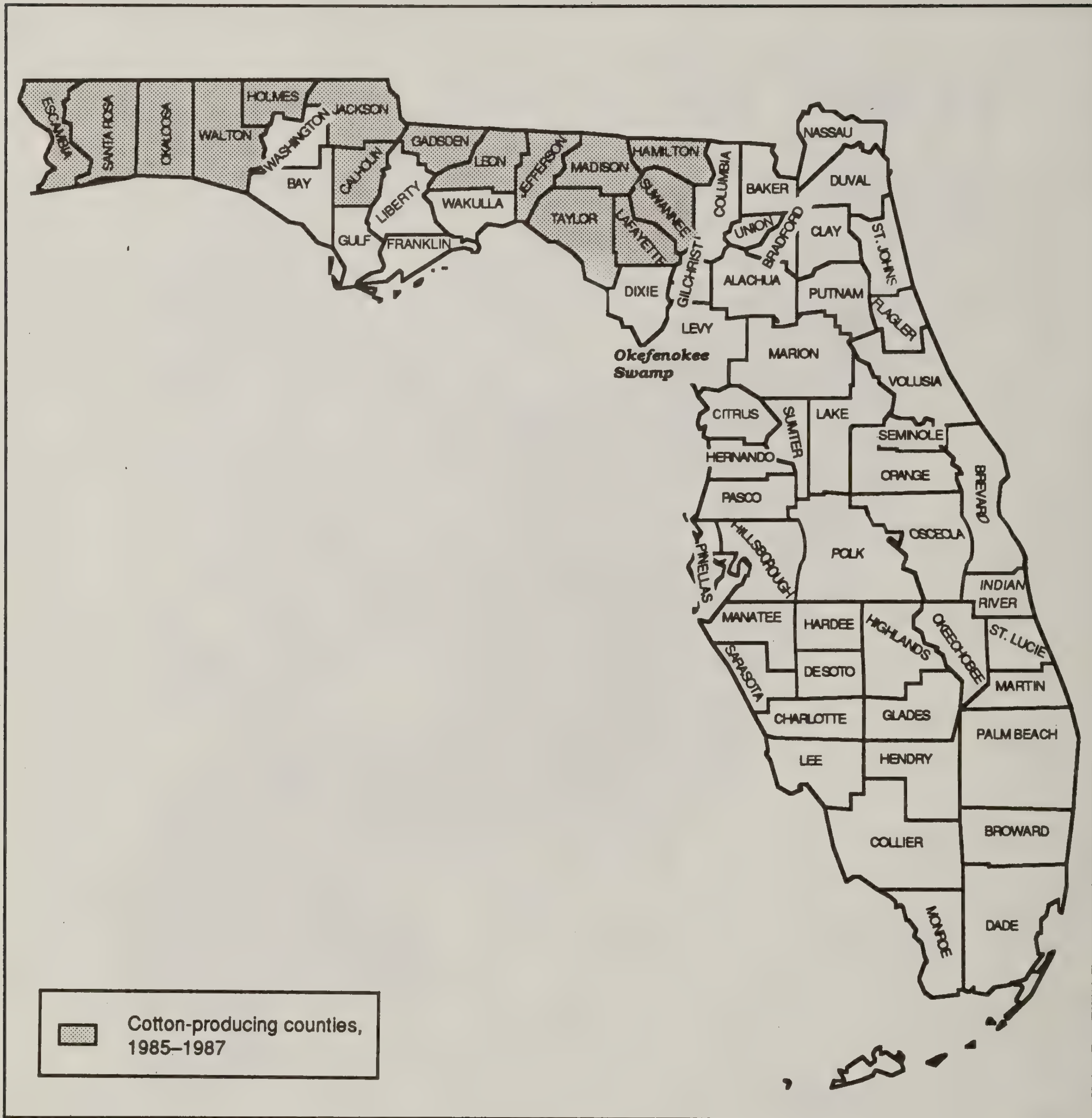

| | | |
|---|---|---|
| Ashley | Drew | Miller |
| Chicot | Greene | Mississippi |
| Clark | Hempstead | Monroe |
| Clay | Jefferson | Phillips |
| Craighead | Lafayette | Poinsett |
| Crittenden | Lee | Prairie |
| Cross | Lincoln | Pulaski |
| Dallas | Little River | St. Francis |
| Desha | Lonoke | Woodruff |

**Cotton-Producing Counties in CALIFORNIA**



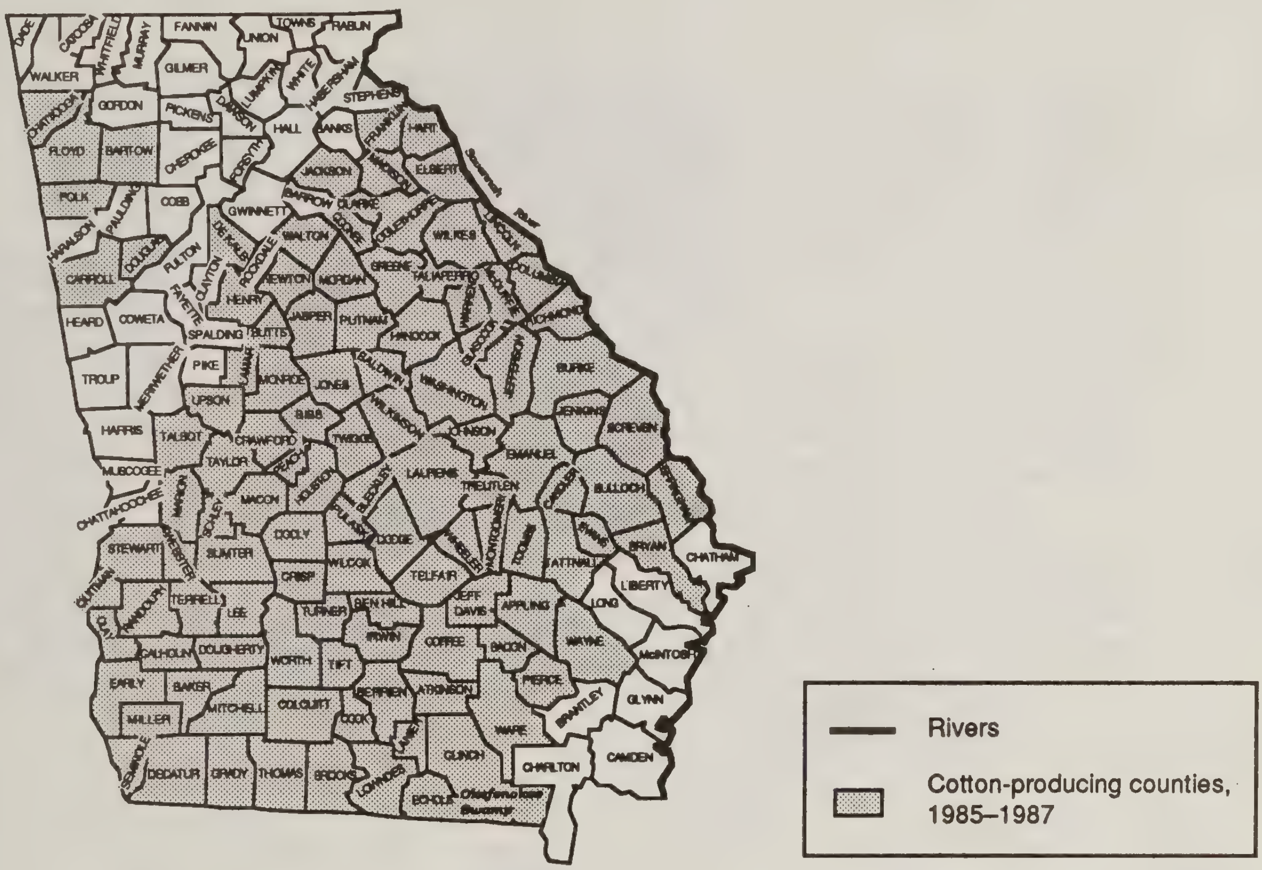

| | | |
|---|---|---|
| Fresno | Kings | Riverside |
| Imperial | Madera | San Bernardino |
| Kern | Merced | Tulare |

## Cotton-Producing Counties in FLORIDA



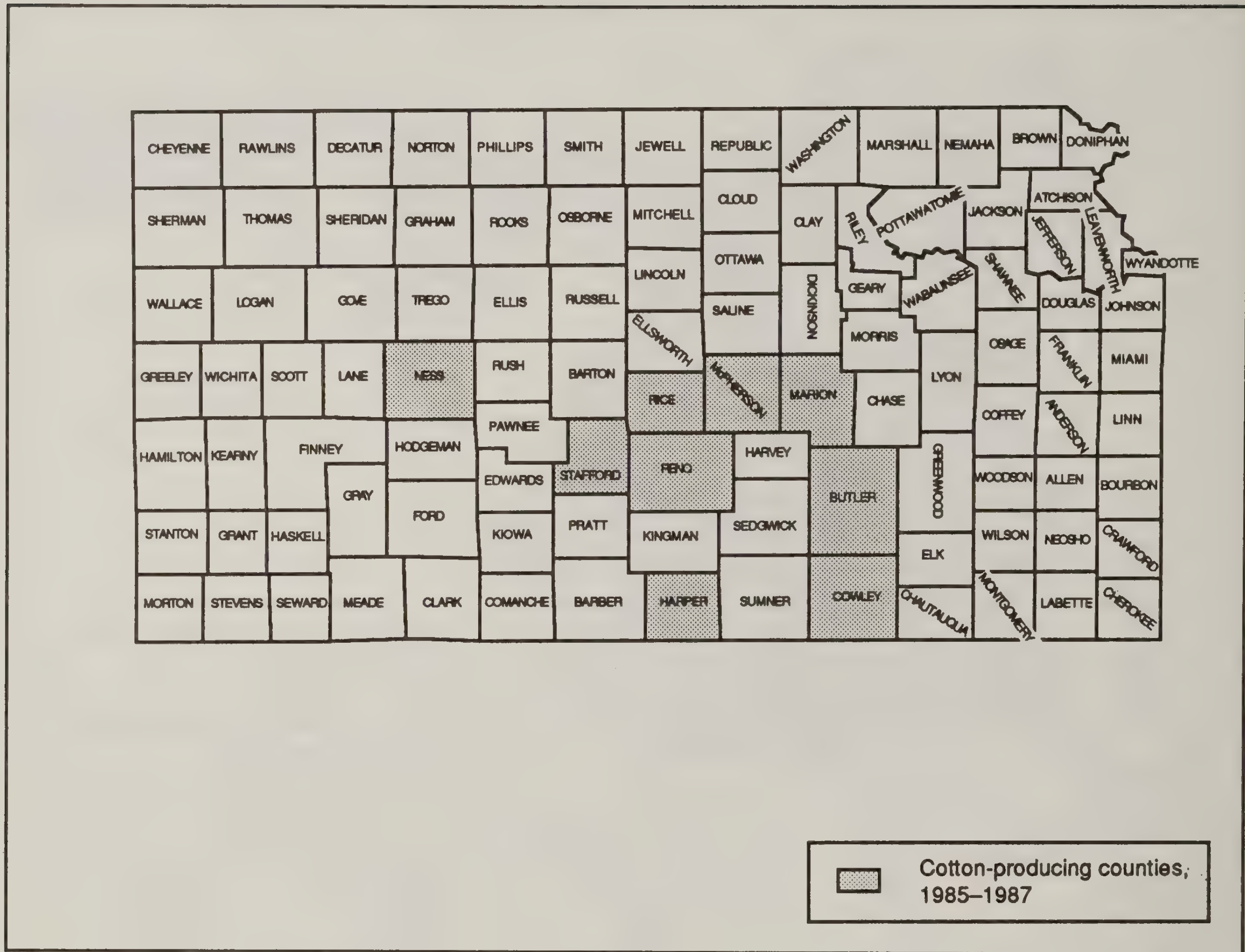

| | | |
|---|---|---|
| Calhoun | Jackson | Okaloosa |
| Escambia | Jefferson | Santa Rosa |
| Gadsden | Lafayette | Suwannee |
| Hamilton | Leon | Taylor |
| Holmes | Madison | Walton |

## Cotton-Producing Counties in GEORGIA



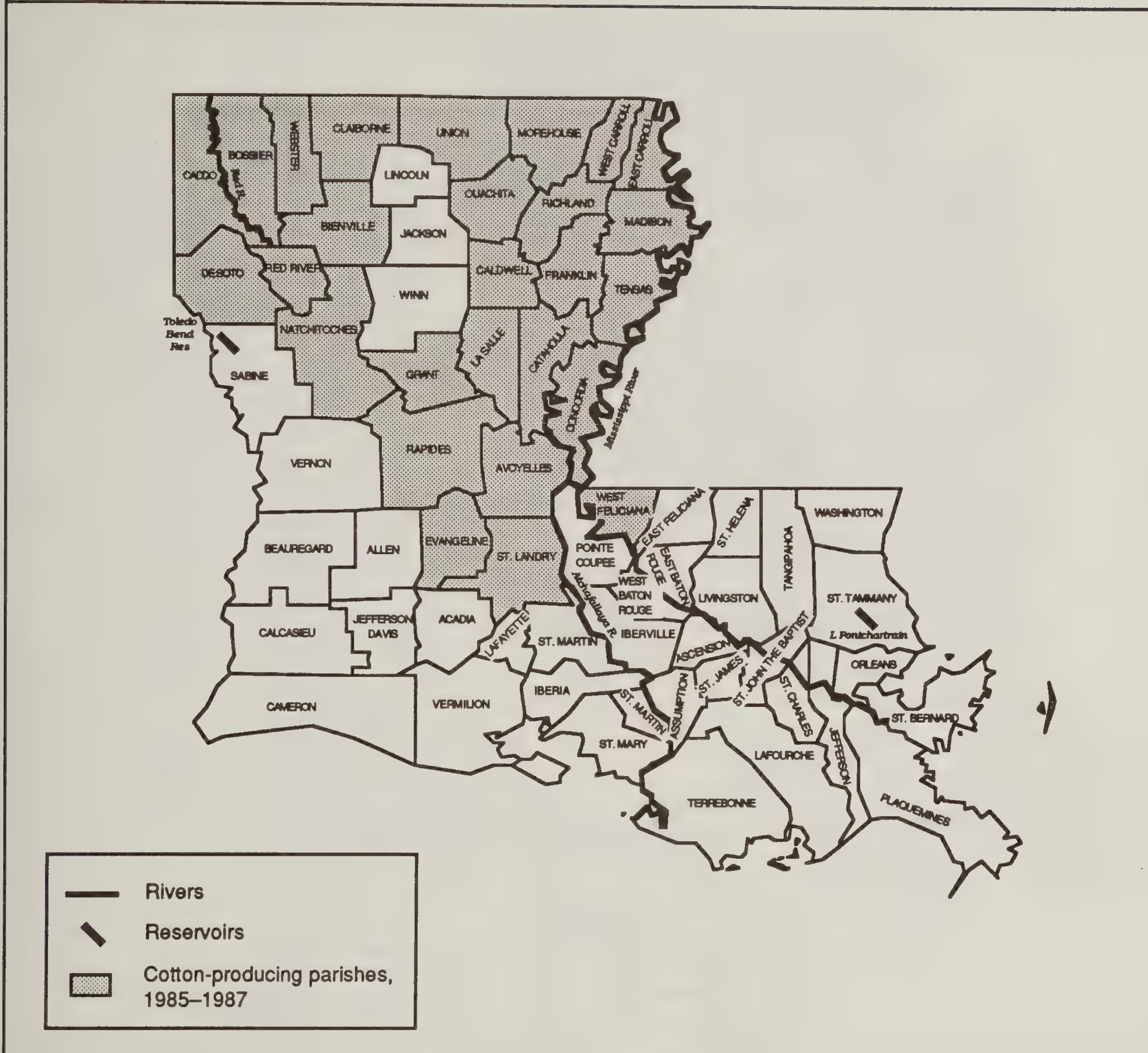

Appling
Atkinson
Bacon
Baker
Baldwin
Bartow
Ben Hill
Berrien
Bibb
Bleckley
Brooks
Bryan
Bulloch
Burke
Butts
Calhoun
Candler
Carroll
Chattooga
Clarke
Clay
Coffee
Colquitt
Columbia
Cook
Crawford
Crisp
De Kalb
Decatur
Dodge
Dooly
Dougherty
Douglas
Early
Echols
Effingham
Elbert
Emanuel
Evans
Floyd
Franklin
Glascock
Grady
Greene
Hancock
Hart
Henry
Houston
Irwin
Jackson
Jasper
Jeff Davis
Jefferson
Jenkins
Johnson
Jones
Lamar
Lanier
Laurens
Lee
Lincoln
Lowndes
Macon
Madison
Marion
McDuffie
Miller
Mitchell
Monroe
Montgomery
Morgan
Newton
Oconee
Oglethorpe
Peach
Pierce
Polk
Putnam
Pulaski
Quitman
Randolph
Richmond
Schley
Screven
Seminole
Stewart
Sumter
Talbot
Taliaferro
Tattnall
Taylor
Telfair
Terrell
Thomas
Tift
Toombs
Treutlen
Turner
Twiggs
Upson
Walton
Ware
Warren
Washington
Wayne
Webster
Wheeler
Wilcox
Wilkes
Wilkinson
Worth

## Cotton-Producing Counties in KANSAS



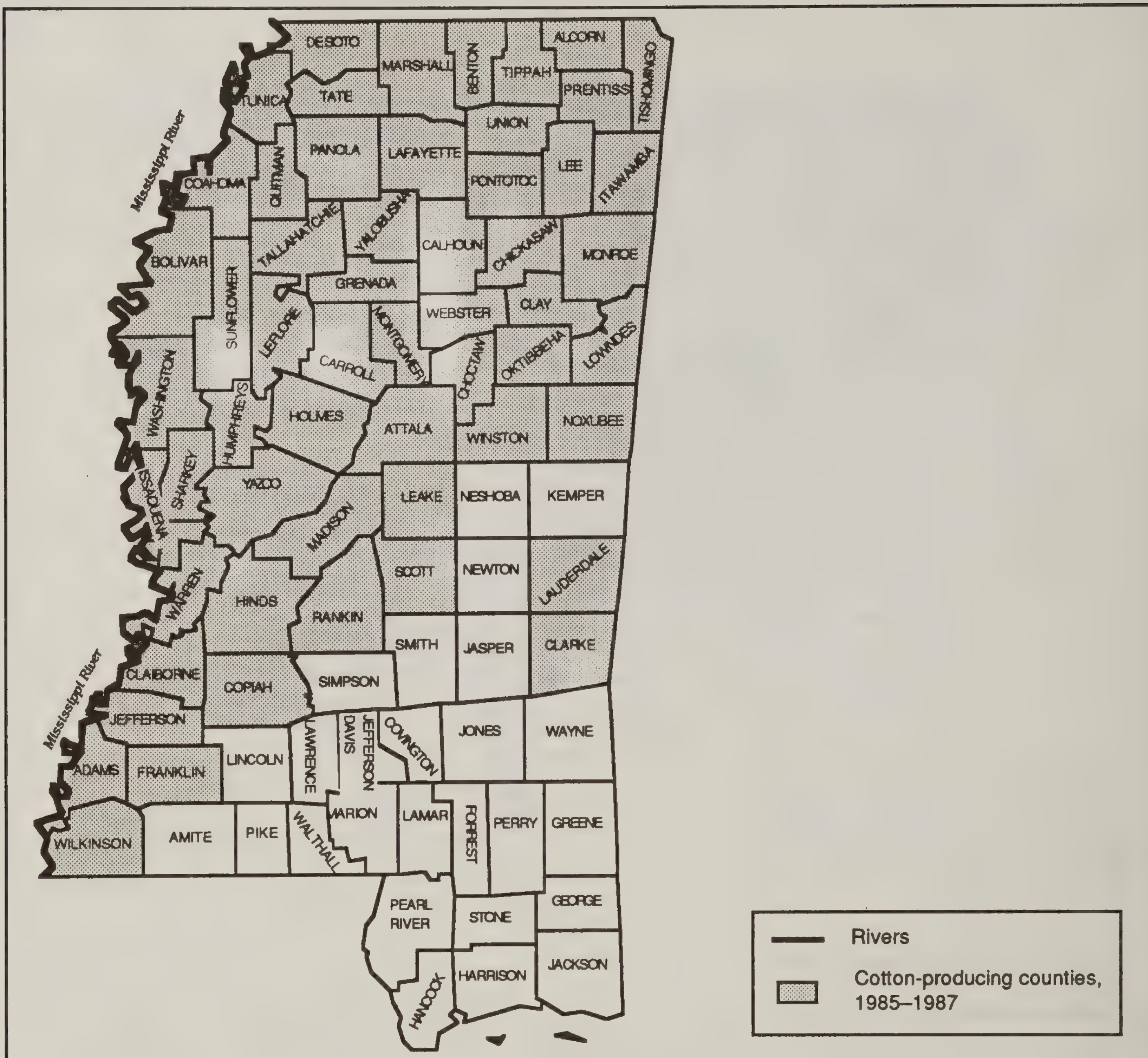

| | | |
|---|---|---|
| Butler | Marion | Reno |
| Cowley | McPherson | Rice |
| Harper | Ness | Stafford |

## Cotton-Producing Parishes in LOUISIANA



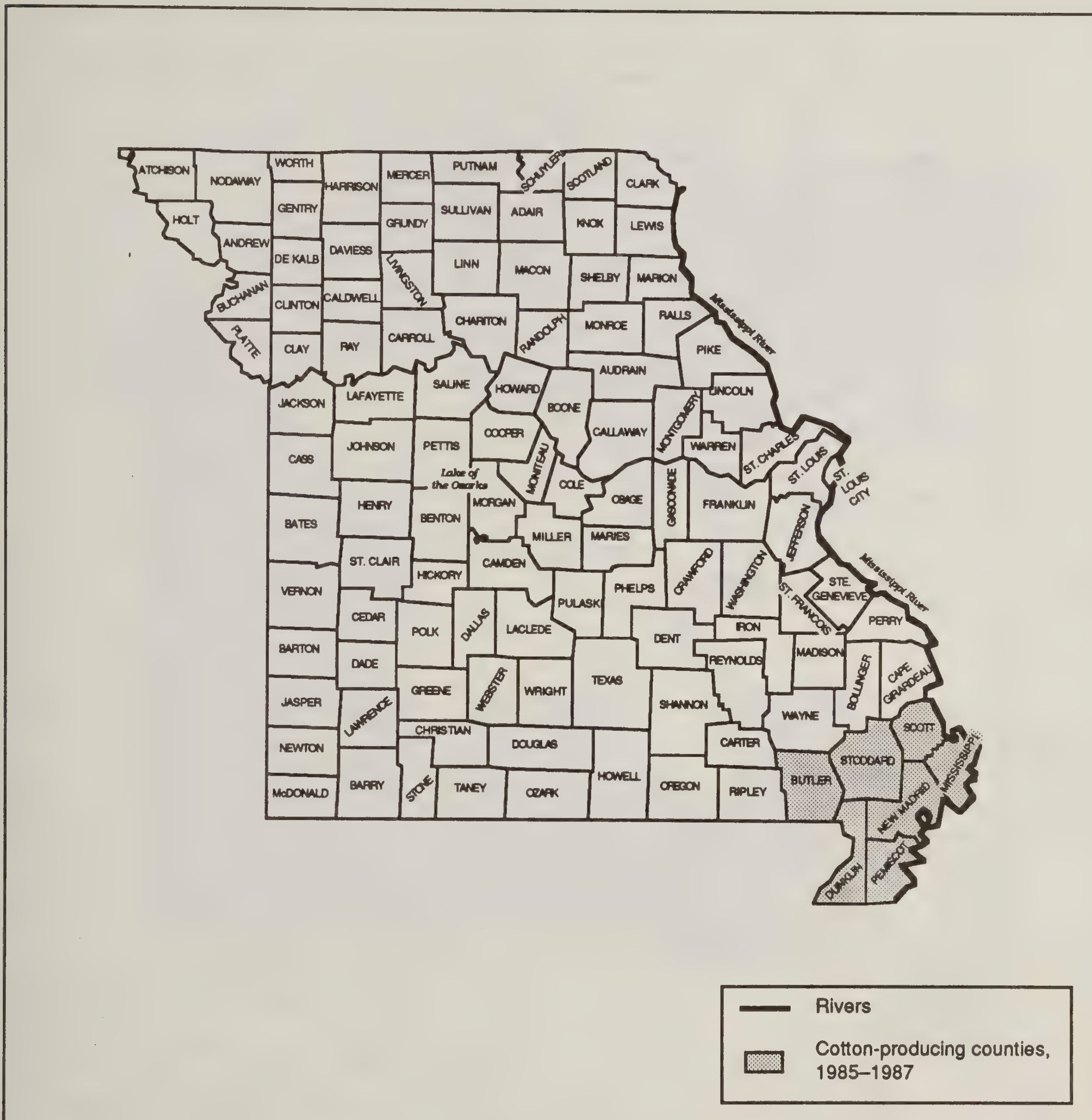

- Avoyelles
- Bienville
- Bossier
- Caddo
- Caldwell
- Catahoula
- Claiborne
- Concordia
- De Soto
- East Carroll
- Evangeline
- Franklin
- Grant
- La Salle
- Madison
- Morehouse
- Natchitoches
- Ouachita
- Rapides
- Red River
- Richland
- St. Landry
- Tensas
- Union
- Webster
- West Carroll
- West Feliciana

## Cotton-Producing Counties in MISSISSIPPI



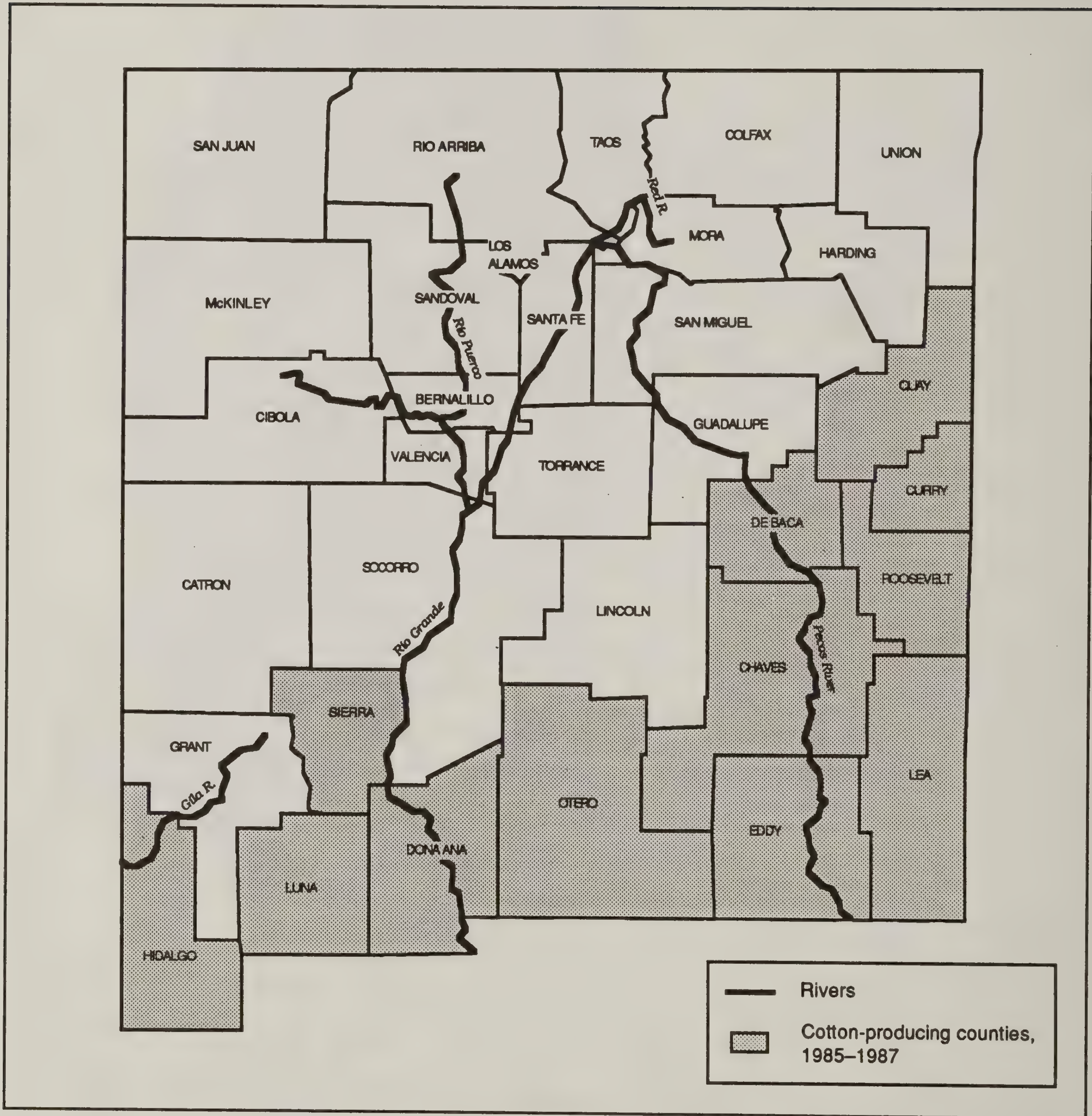

| | | | | |
|---|---|---|---|---|
| Adams | Clay | Jefferson | Noxubee | Tate |
| Alcorn | Coahoma | Lafayette | Oktibbeha | Tippah |
| Attala | Copiah | Lauderdale | Panola | Tishomingo |
| Benton | DeSoto | Leake | Pontotoc | Tunica |
| Bolivar | Franklin | Lee | Prentiss | Union |
| Calhoun | Grenada | Leflore | Quitman | Warren |
| Carroll | Hinds | Lowndes | Rankin | Washington |
| Chickasaw | Holmes | Madison | Scott | Webster |
| Choctaw | Humphreys | Marshall | Sharkey | Wilkinson |
| Claiborne | Issaquena | Monroe | Sunflower | Winston |
| Clarke | Itawamba | Montgomery | Tallahatchie | Yalobusha |
| | | | | Yazoo |

## Cotton-Producing Counties in MISSOURI



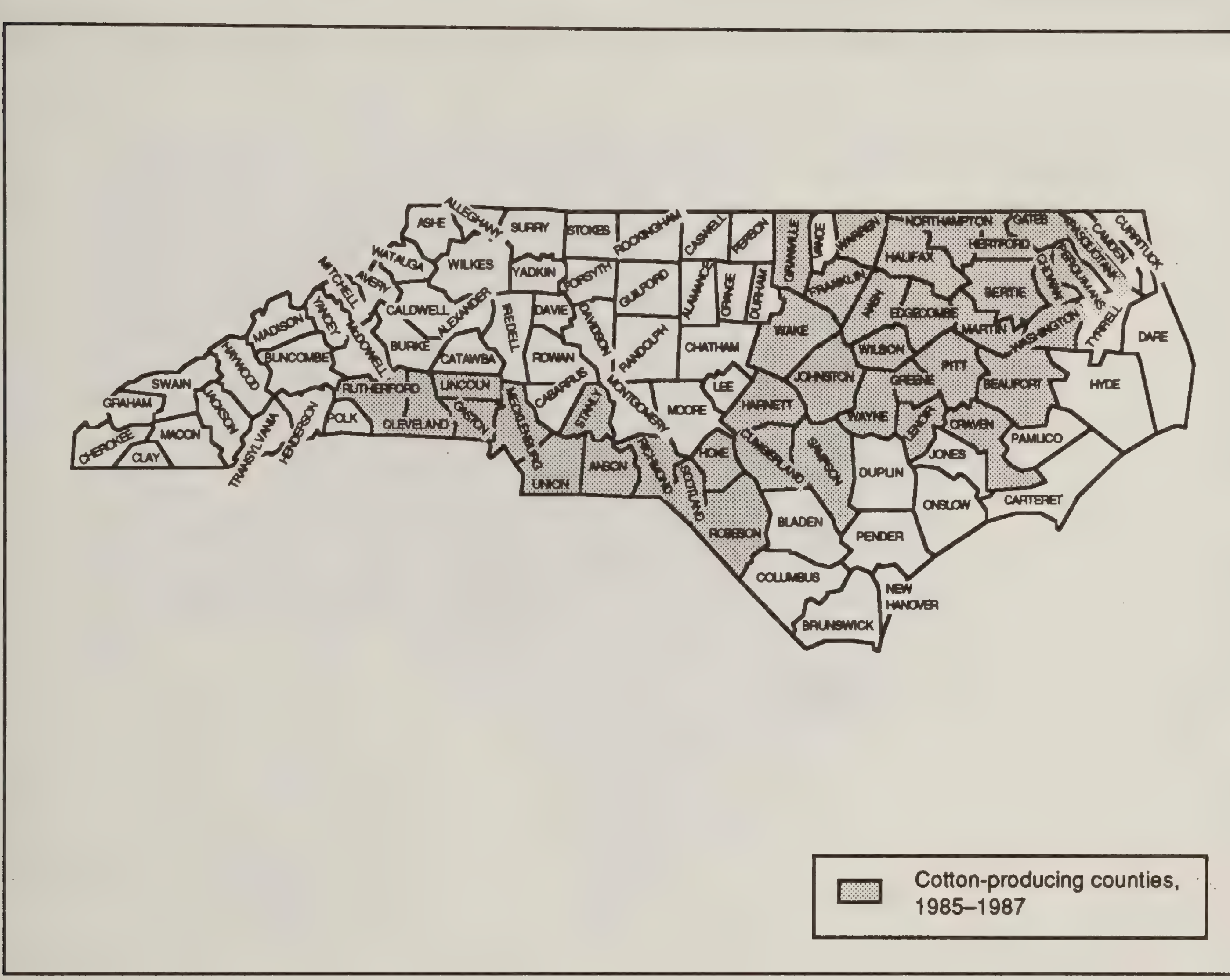

| | | |
|---|---|---|
| Butler | New Madrid | Stoddard |
| Dunklin | Pemiscot | |
| Mississippi | Scott | |

## Cotton-Producing Counties in NEW MEXICO



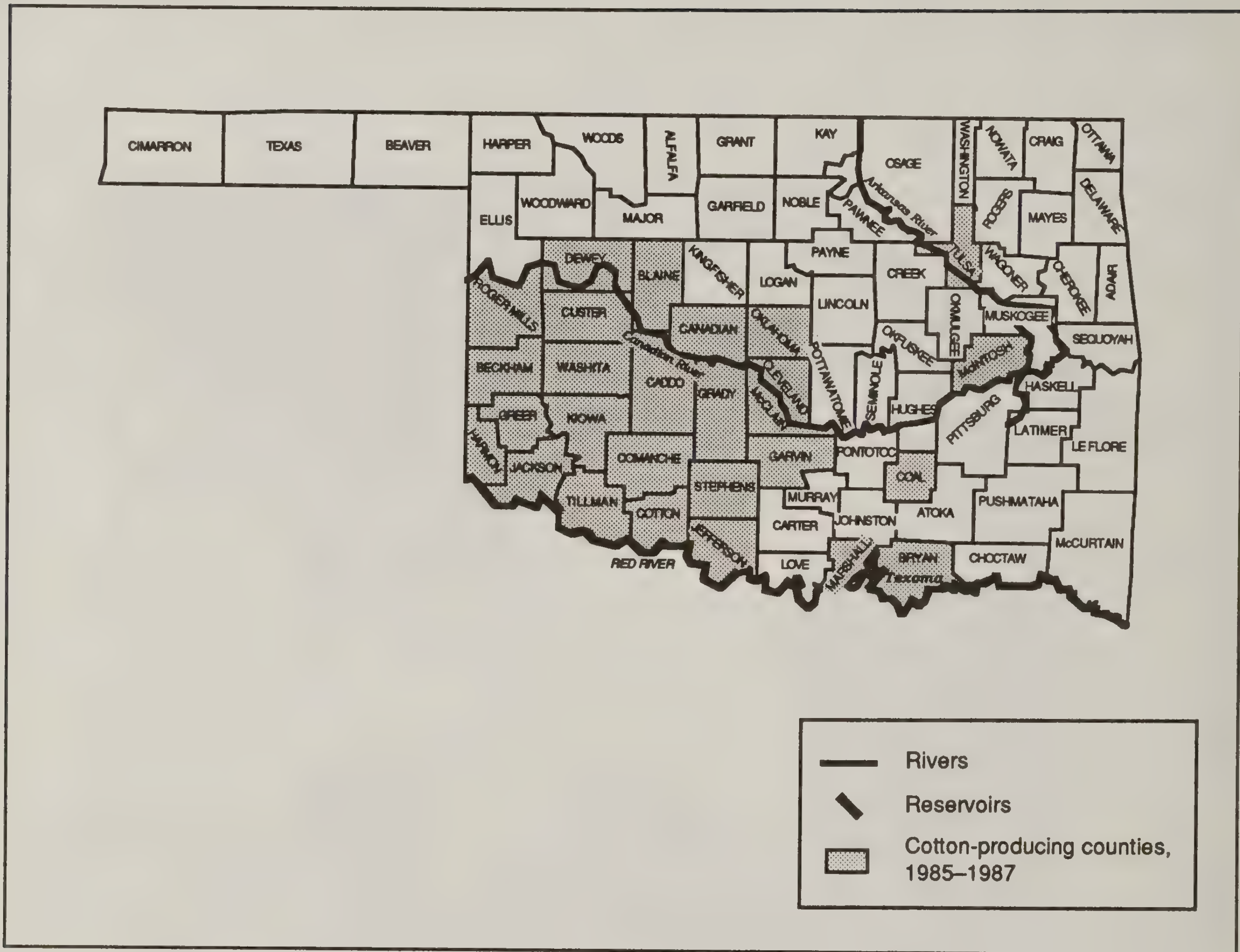

| | | |
|---|---|---|
| Chaves | Eddy | Otero |
| Curry | Hidalgo | Quay |
| De Baca | Lea | Roosevelt |
| Dona Ana | Luna | Sierra |

## Cotton-Producing Counties in NORTH CAROLINA



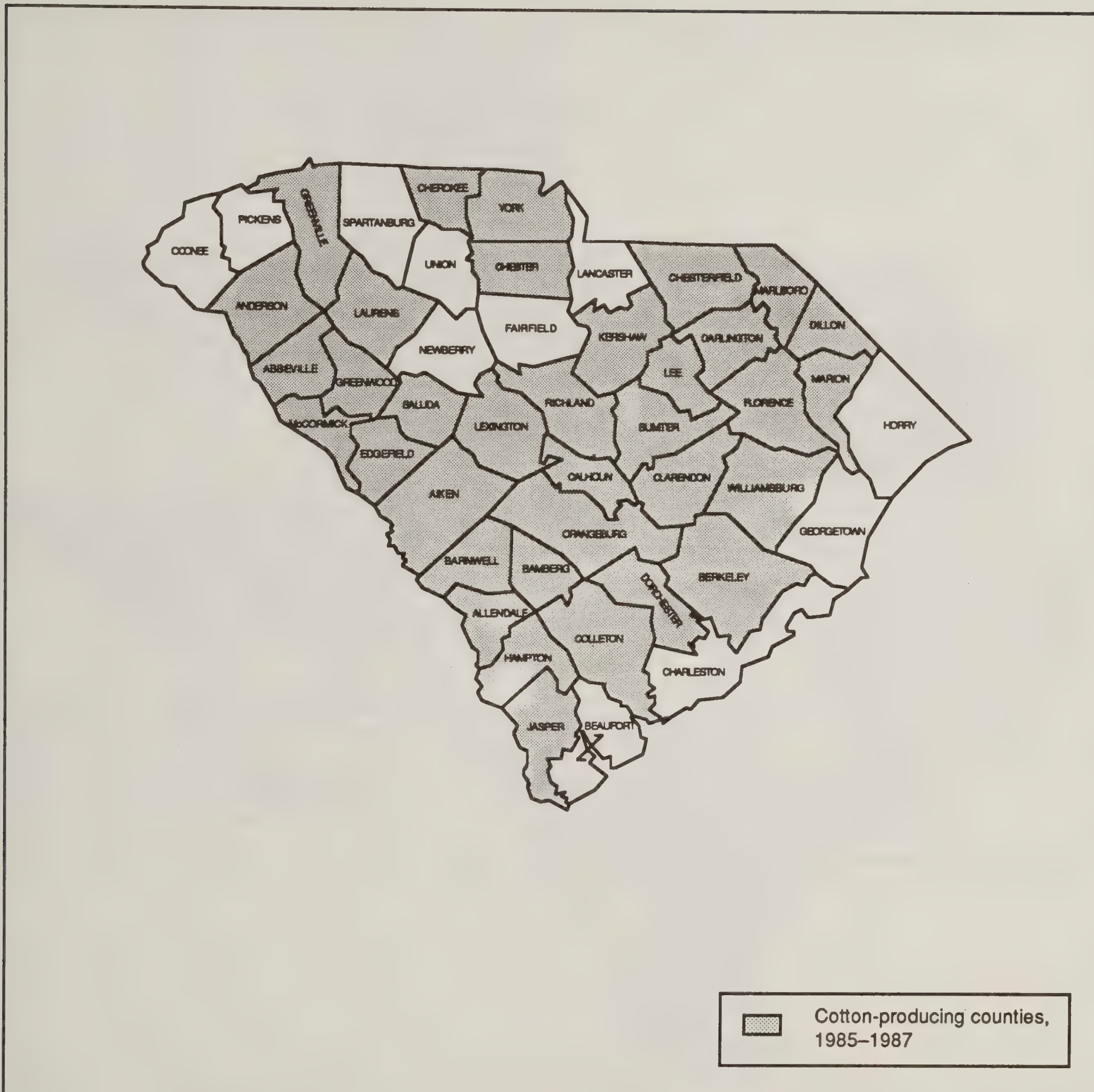

- Anson
- Beaufort
- Bertie
- Chowan
- Cleveland
- Craven
- Cumberland
- Edgecombe
- Franklin
- Gaston
- Gates
- Granville
- Greene
- Halifax
- Harnett
- Hertford
- Hoke
- Johnston
- Lenoir
- Lincoln
- Martin
- Mecklenburg
- Nash
- Northampton
- Pasquotank
- Perquimans
- Pitt
- Richmond
- Robeson
- Rutherford
- Sampson
- Scotland
- Stanly
- Union
- Wake
- Warren
- Washington
- Wayne
- Wilson

## Cotton-Producing Counties in OKLAHOMA



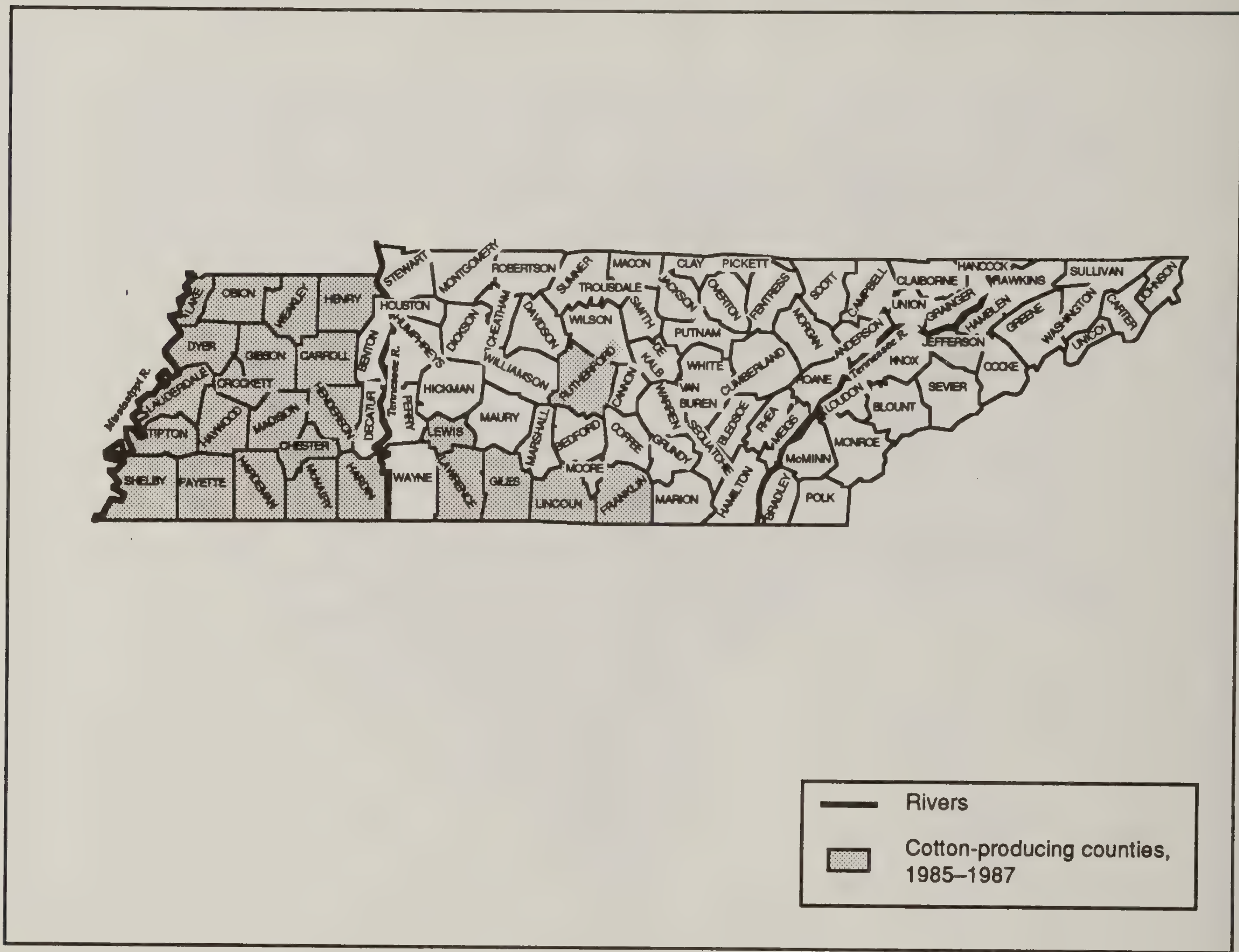

| | | |
|---|---|---|
| Beckham | Custer | Marshall |
| Blaine | Dewey | McClain |
| Bryan | Garvin | McIntosh |
| Caddo | Grady | Oklahoma |
| Canadian | Greer | Roger Mills |
| Cleveland | Harmon | Stephens |
| Coal | Jackson | Tillman |
| Comanche | Jefferson | Tulsa |
| Cotton | Kiowa | Washita |

## Cotton-Producing Counties in SOUTH CAROLINA



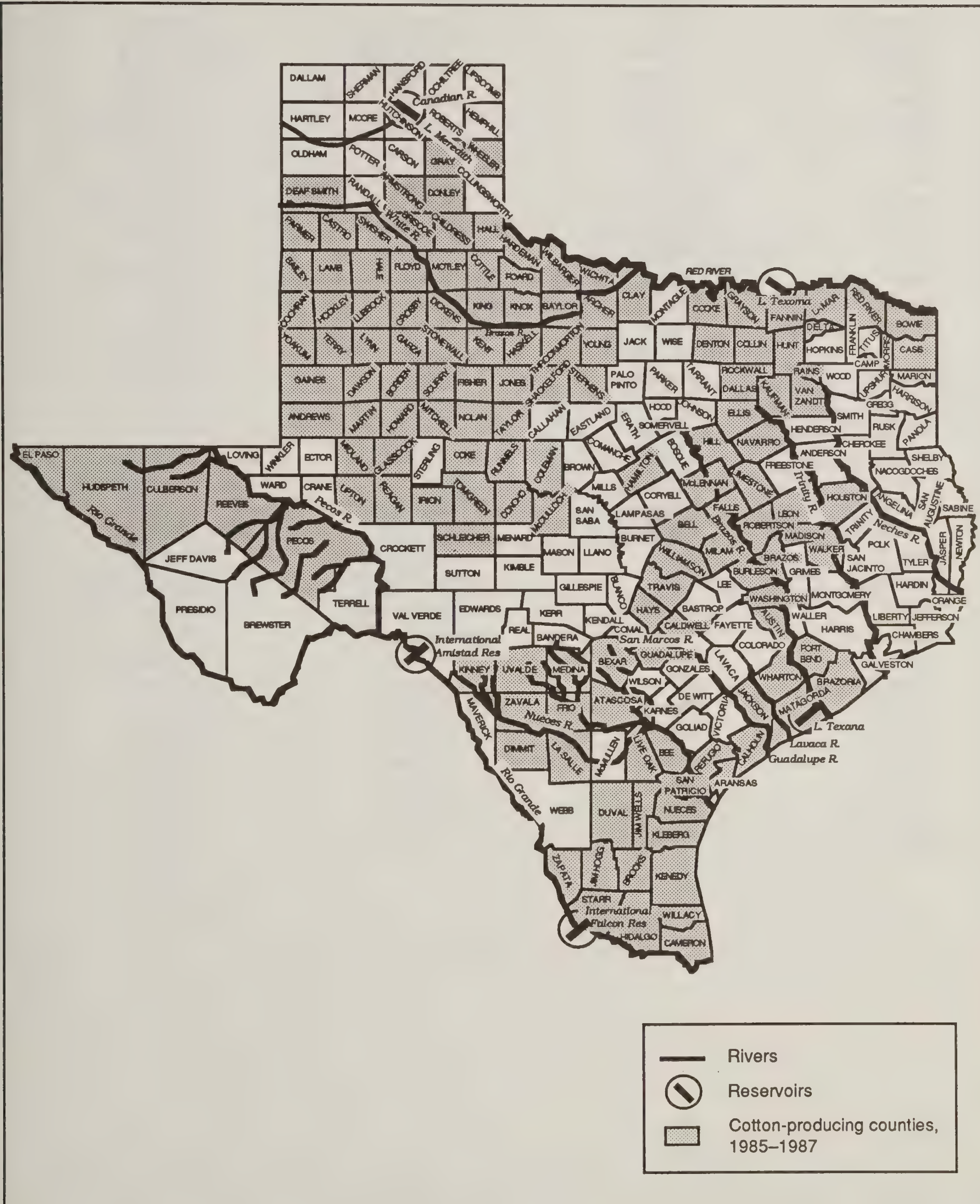

| | | | |
|---|---|---|---|
| Abbeville | Chester | Greenville | Marlboro |
| Aiken | Chesterfield | Greenwood | McCormick |
| Allendale | Clarendon | Hampton | Orangeburg |
| Anderson | Colleton | Jasper | Richland |
| Bamberg | Darlington | Kershaw | Saluda |
| Barnwell | Dillon | Laurens | Sumter |
| Berkeley | Dorchester | Lee | Williamsburg |
| Calhoun | Edgefield | Lexington | York |
| Cherokee | Florence | Marion | |

## Cotton-Producing Counties in TENNESSEE




| | | |
|---|---|---|
| Carroll | Hardin | Madison |
| Chester | Haywood | McNairy |
| Crockett | Henderson | Obion |
| Dyer | Henry | Rutherford |
| Fayette | Lake | Shelby |
| Franklin | Lauderdale | Tipton |
| Gibson | Lawrence | Weakley |
| Giles | Lewis | |
| Hardeman | Lincoln | |

## Cotton-Producing Counties in TEXAS



**Cotton-Producing Counties in TEXAS (continued)**

| | | | |
|---|---|---|---|
| Andrews | Dawson | Hunt | Pecos |
| Archer | Deaf Smith | Irion | Rains |
| Armstrong | Delta | Jackson | Reagan |
| Atascosa | Denton | Jim Hogg | Red River |
| Austin | Dickens | Jim Wells | Reeves |
| Bailey | Dimmit | Jones | Refugio |
| Baylor | Donley | Kaufman | Robertson |
| Bee | Duval | Kenedy | Rockwall |
| Bell | Ellis | Kent | Runnels |
| Bexar | El Paso | King | San Patricio |
| Borden | Falls | Kinney | Schleicher |
| Bowie | Fannin | Kleberg | Scurry |
| Brazoria | Fisher | Knox | Shackelford |
| Brazos | Floyd | La Salle | Starr |
| Briscoe | Foard | Lamar | Stephens |
| Brooks | Fort Bend | Lamb | Stonewall |
| Burleson | Frio | Leon | Swisher |
| Caldwell | Gaines | Limestone | Taylor |
| Calhoun | Garza | Live Oak | Terry |
| Cameron | Glasscock | Lubbock | Throckmorton |
| Cass | Gray | Lynn | Tom Green |
| Castro | Grayson | Madison | Travis |
| Childress | Guadalupe | Martin | Upton |
| Clay | Hale | Matagorda | Uvalde |
| Cochran | Hall | McCulloch | Van Zandt |
| Coke | Hamilton | McLennan | Walker |
| Coleman | Hardeman | Medina | Ward |
| Collin | Haskell | Midland | Washington |
| Collingsworth | Hays | Milam | Wharton |
| Concho | Hidalgo | Mitchell | Wheeler |
| Cooke | Hill | Motley | Wichita |
| Cottle | Hockley | Navarro | Wilbarger |
| Crosby | Houston | Nolan | Willacy |
| Culberson | Howard | Nueces | Williamson |
| Dallas | Hudspeth | Parmer | Yoakum |
| | | | Young |
| | | | Zapata |
| | | | Zavala |

## Cotton-Producing Counties in VIRGINIA


| | | |
|---|---|---|
| Brunswick | Greensville | Southampton |

# Appendix B

# Risk Assessment

## Purpose

This appendix assesses the risks to human health and nontarget organisms, including wildlife and domestic animals, from the use of four chemical insecticides—malathion, azinphos-methyl, diflubenzuron, and methyl parathion—for the boll weevil eradication and suppression programs in cotton-producing States. Xylene, an inert ingredient in the microencapsulated formulation of methyl parathion, is also assessed.

In addition to an active ingredient, insecticide formulations usually contain inert ingredients. Although some inert ingredients may be listed by name on the pesticide label, the Environmental Protection Agency (EPA) does not require manufacturers to do this. The identity of the inert ingredients in a formulation is proprietary information. Proprietary inert ingredients are not analyzed in this risk assessment; however, xylene, a nonproprietary inert ingredient in the Penncap M® formulation of methyl parathion, is assessed. These ingredients may be natural or synthetic, and they are added to a formulation to provide a carrier to facilitate the effectiveness of pesticide applications.

## Organization of This Appendix

Appendix B has nine sections. Section B1 provides an overview and describes the methodology of the risk assessment. Sections B2 through B4 cover human health risk analysis. Section B2, the human hazard analysis, is an overview of the toxic properties of each insecticide in terms of toxicity to humans, including known or suspected carcinogenic risk. Section B3, the human exposure analysis, describes the structure, methods, and assumptions used to estimate human exposure. Section B4, the human health risk analysis, presents the methodology used for assessing human health risks and the estimated risk to the public and workers from insecticide exposure. Sections B5 through B7 describe information necessary for nontarget species analysis. Section B5, nontarget species hazard analysis, discusses the toxic properties of each insecticide as it relates to terrestrial and aquatic species. Section B6, the nontarget species exposure analysis, discusses nontarget exposure analysis methods and assumptions used in estimating exposures. Section B7, nontarget species risk analysis, gives the methodologies used in assessing the estimated risks to nontarget species. Environmental fate and modeling methods are described in section B8. The chemical properties of each insecticide are examined to determine their potential persistence and transport in the environment. Section B9 contains all references cited in appendix B.

# Appendix B

# Risk Assessment

This appendix [illegible] uses, including [illegible] chemical insecticides [illegible] control parasitoids [illegible] grown in cotton grid [illegible] microencapsulated formulation [illegible]

In addition to [illegible] common trait ingredients. Although [illegible] listed by users on the pesticide label [illegible] Agency (EPA) does not require [illegible] of the inert ingredients [illegible] Frequently [illegible] however, [illegible] formulation [illegible] natural or synthetic [illegible] Exposed to the inert [illegible]

Appendix B has [illegible] describes the methodology [illegible] Risk over human health [illegible] analysis [illegible] an overview of the [illegible] terms of toxicity [illegible] [illegible] Section B[illegible] methods, and assumptions [illegible] for the human health risk analysis [illegible] assessing human health risks [illegible] [illegible] exposure [illegible] information necessary for [illegible] target [illegible] results of species-based analysis [illegible] insecticide [illegible] relates to terrestrial and [illegible] nontarget species exposure analysis, [illegible] analysis methods and assumptions used in [illegible] Section B7, monitoring [illegible] risk analysis [illegible] [illegible] in assessing [illegible] estimated risks to nontarget [illegible] mental fate and modeling methods [illegible] developed [illegible] [illegible] of each insecticide [illegible] potential [illegible] and [illegible] of the [illegible] [illegible] in Appendix [illegible]

## Section B1

## Overview of the Risk Assessment

### Introduction

This risk assessment examines the potential health effects to the representative human population and nontarget organisms that might be exposed to insecticides as a result of activities associated with the boll weevil eradication and suppression programs. The exposed human population is divided into two groups. The first group—the public—includes passersby or nearby residents. The second group—workers—includes aerial and ground applicators, observers, and other personnel directly involved in the application of insecticides. The nontarget organisms assessed include representative species of birds, mammals, reptiles, amphibians, insects, and fish.

The risk assessment includes analyses of a range of possible exposures that could result from insecticide application from those that are most likely to occur to those that are extremely unlikely. A set of assumptions concerning the characteristics of typical insecticide applications is used to estimate the doses to workers and the nearby public that may potentially occur as a result of routine application operations. A second set of assumptions, based on extreme values of the routine-typical application characteristics ("routine-extreme"), is used to obtain the maximum exposure that is not likely to be exceeded, except in the case of an accident. A third set of assumptions about accidents is used to estimate doses to workers and the public that may result from direct exposure to a spray mix or concentrate. Exposure refers to the amount of a chemical in the environment that is available to be taken into an organism, while dose is the actual amount that enters an organism's body.

Health risks are evaluated by comparing dose estimates for workers and the public with appropriate hazard levels, as determined in tests on laboratory animals and human volunteers, where available. This analysis estimates the risk of chronic health effects arising from a single exposure or from repeated exposures over various time periods for each insecticide. In addition, malathion and azinphos-methyl are analyzed to estimate the risk of carcinogenicity as a result of predicted insecticide exposures. The risk of carcinogenicity is also calculated for diflubenzuron. Although the data on the carcinogenicity of diflubenzuron are inconclusive, the possibility of carcinogenicity cannot be ruled out. (Methyl parathion and xylene were not included in the carcinogenic risk analysis because there is no evidence in EPA records that they may be carcinogens.) The risk of heritable mutations is evaluated qualitatively, based on available data from laboratory animal studies. Exposures to multiple insecticides are addressed in a qualitative discussion of synergistic effects. The health effects on terrestrial and aquatic species from the insecticides were determined by comparing estimated exposures to lethal levels established in laboratory animal studies.

## Structure of the Risk Assessment

Assessing the risk of program insecticide use effects on human health requires not only estimating the possible types of exposures that could occur as a result of insecticide applications and associated activities, but also the probability and extent of adverse health effects from such exposures. This risk assessment uses the following three principal analytical elements described by the National Research Council (1983) as necessary to characterize the potential adverse health effects of human exposures to existing or introduced hazards in the environment:

- **Hazard Analysis** requires gathering information for determining the toxic properties of each insecticide. Human hazard levels are derived primarily from the results of laboratory studies of animal models, such as rats, mice, and rabbits. This information is supplemented, where appropriate, with data on human poisoning incidents, field studies of other organisms, and chemical structure. Nontarget species hazard levels are drawn from laboratory and field studies.

- **Exposure Analysis** involves estimating single and multiple exposures to those persons and nontarget species potentially exposed to the insecticides and determining the doses likely to result from such estimated exposures.

- **Risk Analysis** requires comparing the hazard information with the dose estimates to predict the health effects to individuals under the given conditions of exposure.

The relationships among these three components are illustrated in figure B1-1.

This risk assessment identifies uncertainties, such as areas where scientific studies are unavailable, and describes how those uncertainties were addressed to produce the results of the analyses. The following describes how the risk assessment used the three analytical elements mentioned above.

## Hazard Analysis

The hazard involved in using each of the insecticides was determined from extensive literature searches. In addition, all relevant available data that were submitted to EPA in support of the registration and reregistration of these insecticides were reviewed for required toxicity reference levels—in particular, rat median lethal doses ($LD_{50}$s), systemic and reproductive no-observed-effect levels (NOELs), and data concerning cancer and mutagenicity. (A median lethal dose is the amount of a substance that will kill 50 percent of a laboratory test population.) The most conservative values (that is, the values reflecting the greatest hazard potential) were used in the quantitative risk analysis. Where scientific uncertainty exists for a particular insecticide on a specific toxic effect—for example, mutagenicity—the area is identified and a conclusion is drawn about the effect based on the available data. Cancer potency values derived from laboratory animal tumor data were computed for the insecticides that have demonstrated the potential to

Figure B1-1. Components of the Risk Assessment Process

### Hazard Analysis

- Identify what kinds of health effects have been observed in laboratory animals and at what levels of exposure
- Identify any health effects that have been observed in humans
- Determine median lethal dose ($LD_{50}$) for acute effects from laboratory rat study
- Determine lowest no-observed-effect levels (NOELs), if possible, for general chronic toxic effects, reproductive effects, and birth defects
- Determine whether the pesticide potentially causes cancer or mutations
- Identify data gaps in toxicity information

### Exposure Analysis

- Identify people exposed
- Identify routes of exposure
- Estimate how much each person would receive by each exposure route using both routine and extreme case scenarios
- Estimate frequency and duration of exposure
- Calculate doses

### Risk Analysis

- Compare doses to NOELs and $LD_{50}$s and discuss probability of acute and chronic effects (including birth defects) for routine, extreme, and accident scenarios
- Conduct extreme case analysis for cancer risk
- Identify extreme case risk of mutations

cause a carcinogenic response in mammals. Each insecticide was also evaluated in terms of its potential to cause neurotoxic, immunotoxic, and synergistic effects.

## Exposure Analysis

To assess the risks associated with insecticide use, various aspects of the boll weevil control programs were examined. Major aspects of these programs that determine potential levels of insecticide exposure were identified, including human activities in or near treated fields, application methods and rates, and the size and configuration of cotton fields.

### Insecticide Spraying Operations

The insecticides examined in this risk assessment may be applied aerially, using fixed-wing or helicopter aircraft, or by ground application methods, including hiboys and mist blowers. The number of cotton fields, the acreage treated, and the number of applications may be expected to vary in any given year. In addition, the geographical area that may be treated in an eradication or suppression program may vary during the course of any program increment.

The area treated for boll weevil control with various insecticides by individual growers also varies. In 1987, approximately 3,758,401 acres were treated for boll weevils. In the same year, however, more than 5 million acres were infested with boll weevils. Chapters 1 and 2 of the EIS contain further details about current grower operations and the existing cooperative control program.

### Affected Populations

In the human exposure analysis, both typical and extreme dose estimates were made for routine application operations. Doses from accidents were also estimated.

For the analysis of public health effects, dose estimates were made for nearby residents assumed to be exposed as a result of routine operations through one of the following routes:

- Consumption of garden vegetables that have received insecticide drift (at 100 and at 25 feet)
- Consumption of venison from deer that have consumed forage and water contaminated with insecticide and from a deer that has been directly sprayed or received spray drift at 25 feet
- Consumption of berries that have received insecticide drift (at 100 and at 25 feet)
- Consumption of water that has received drift residues (at 100 and at 25 feet)
- Receipt of dermal and inhalation exposure from insecticide drift (at 500 and at 100 feet)

- Consumption of fish from a pond that has received spray drift at 25 feet or has been directly sprayed

Also, routine doses were estimated for six types of workers: pilots, mixer/loaders, environmental monitoring team members, observers, hiboy operators, and mist blower operators.

Because all human activities involve the possibility of error, the use of insecticides in boll weevil control operations involves the possibility that humans may inadvertently receive unusually high exposures to the pesticides because of accidents. To examine what potential health effects could occur in an accident, the following accidental situations were analyzed:

- Spills of pesticide concentrate and mix on a worker's skin

- Direct accidental spraying of a worker from a broken hose

- Direct aerial spray of a member of the public from aerial application

- Aerial spray of a member of the public from a distance of 25 feet

- Consumption of water from a reservoir that has received an 80-gallon spill of insecticide from an aerial applicator

- Consumption of legumes or berries that have been directly sprayed

In addition, the nontarget species exposure analysis estimates impacts on terrestrial wildlife with respect to several routes of exposure, including consumption of diet items, dermal exposure from vegetation contact or direct spray, and inhalation exposure. Impacts to aquatic life are also evaluated using estimated water concentrations for exposure levels.

## Risk Analysis

Human health risks from the boll weevil programs were evaluated by comparing the doses to workers and the general public that were calculated for routine-typical, routine-extreme, and accidental exposure scenarios to the laboratory-determined toxicity levels described in the hazard analysis. The risks of threshold effects were evaluated in terms of margin of safety (MOS), which is the ratio of the dose estimated in the exposure analysis to the NOEL. Risk increases as the estimated dose approaches the laboratory toxicity level or as the MOS gets smaller.

An insecticide's carcinogenic potential was evaluated differently. It was assumed that an insecticide with the demonstrated potential to cause cancer in laboratory animals has some probability of causing cancer at any dose level; therefore, no threshold level is considered. Animal studies were used to determine the relationship between carcinogenic risk and exposure; the laboratory data were then adjusted to reflect the lower dose ranges, larger body size, and longer life span of humans. The risk of cancer was calculated for various categories of people who

may be exposed to the insecticides, based on estimated typical, extreme, and accidental exposures, and the extrapolation of those exposures, based on an estimated average daily exposure over a 70-year lifetime.

The risk of heritable mutations was based on available test data on the data bacteria, yeasts, plants, mammalian cells in culture, and animals, but the data were not quantified. Rather, a qualitative judgment was made concerning the potential for the insecticide to cause genetic mutations in humans at the dose levels likely to be experienced as a result of boll weevil insecticide applications. Where appropriate, that risk was compared with the insecticide's cancer risk.

Cumulative risk for individuals is discussed in terms of lifetime exposures to a given insecticide for workers and the public. Risk of synergistic effects is discussed in terms of the available evidence of enhanced toxicity in mixtures of two or more of the insecticides used on cotton crops.

Risks to wildlife were evaluated by comparing the typical and extreme doses to the $LD_{50}$s for representative avian, mammalian, reptilian, amphibian, insect, and domesticated species. Risks to fish and aquatic invertebrate species were calculated for organisms in a pond that receives drift or is directly sprayed. The results of a runoff analysis were used to estimate risks from the eradication and suppression alternatives to species in the Red River in Texas, the Sunflower River in Mississippi, the Tennessee River in Alabama, the Gila River in Arizona, and the Flint River in Georgia. The effects of runoff into smaller rivers and creeks (Neal's Creek in North Carolina, the Pearl River in Mississippi, Leon Creek in Texas, and Aravaipa Creek in Arizona) were analyzed as well. The estimated environmental concentrations (EECs) were compared to the median lethal concentrations ($LC_{50}$s) for the representative aquatic species.

# Section B2

# Human Health Hazard Analysis

## Introduction

This section presents the results of the human hazard analysis—a review of available toxicological information on the insecticides proposed for use in the National Boll Weevil Cooperative Control Program. First, sources of toxicity information used in the hazard analysis are described. Second, the terminology of laboratory toxicity testing is defined, which is subsequently used in each description of the insecticide's toxic properties. Third, the toxicity of each insecticide, including potential carcinogenicity and mutagenicity, is summarized. Fourth, the toxicity of one nonproprietary inert ingredient is summarized.

## Sources of Toxicity Information

Much of the data on pesticide toxicity has been generated to comply with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended (7 USC 136 et seq.), which establishes procedures for the registration, classification, and regulation of all pesticides. The Environmental Protection Agency (EPA) is responsible for implementing FIFRA. EPA Registration Standards are thorough reviews of all data submitted for registration or reregistration of a chemical and are available through EPA's Freedom of Information Office. In addition, the EPA Integrated Risk Information System (IRIS) provides toxicity study data used to determine acceptable human levels of exposure. Toxicity levels and related information from the series of studies submitted for registration are compiled by EPA into summary tables called "tox one-liners" that are available on request from EPA's Freedom of Information Office. EPA has compiled "science chapters" on many of the pesticides and made them available as well. In addition, there is a large body of toxicity information in peer-reviewed journals and reference books, including Casarett and Doull's Toxicology (Klaassen et al., 1986) and Pesticides Studied in Man (Hayes, 1982a).

The Animal and Plant Health Inspection Service (APHIS) conducted an extensive literature search to ensure that all of the relevant, available information was used in this risk analysis. Many computerized literature retrieval data bases were searched to locate current literature on the toxicity of the insecticides, including Medline, Hazardous Substances Databank, the Registry of Toxic Effects of Chemical Substances, Agricola, and Biosis Previews.

Whenever possible, studies that have been reviewed and validated by EPA were used to set toxicity reference levels mentioned in this analysis. No studies deemed invalid by EPA were used in the risk assessment.

## Hazard Analysis Terminology

Because of obvious limitations on the testing of chemicals on humans, most judgments about the potential hazards of pesticides to humans are based on the results of toxicity tests on laboratory animals. These toxicity test results are supplemented by information on actual human poisoning incidents and effects on human populations when they are available. The discussion of laboratory toxicity testing that follows is extracted primarily from Hayes (1982b); Klaassen et al. (1986); and Loomis (1978).

### Laboratory Toxicity Testing

Toxicity tests are designed to measure specific toxic endpoints, such as fatality or cancer, and toxicity reference levels, such as a no-observed-effect level (NOEL), in animals exposed to the chemicals. Toxicity tests vary according to the test species used, test duration, and route of administration.

Most toxicity testing is done to establish threshold levels. Threshold levels are dose levels at which toxic effects are first observed in test animals. Examples of toxic effects include pathologic injury to body tissue; body dysfunctions, such as respiratory failure; or a toxic endpoint, such as birth defects. Threshold dose levels cannot be determined exactly; however, a NOEL is an experimentally determined dose at which there is no statistically or biologically significant increase in frequency or severity of an adverse effect in individuals in an exposed group, when compared with individuals in an appropriate control or unexposed group.

Chemicals are generally thought to possess no threshold level for cancer and mutations; thus, these toxic endpoints may occur (with a certain level of probability) even in the presence of extremely small quantities of the substances.

#### Test Animal Species

Laboratory test animals function as models of the likely effects of a pesticide in humans. Ideally, the test animal should metabolize the compound the same as a human would and should have the same susceptible organ systems. On a body-weight basis, humans generally are more susceptible to effects of compounds than experimental animals by an approximate factor of 10 (Klaassen et al., 1986). Results of animal tests are directly extrapolated to humans by adjusting for differences in body weight and body surface area (as related to metabolic rate). Although no single test species has proven ideal, a number of species have proven to be reliable indicators for certain types of toxicity tests, routes of administration, and types of chemicals—in particular, rats, mice, rabbits, hamsters, guinea pigs, dogs, and monkeys. Rats and mice are most commonly used for toxicity testing because of their low cost, relative ease of handling, documentation of genetic background, documentation of susceptibility to disease, and relatively short life span (2 to 3 years) (ENVIRON, 1988).

### Duration of Toxicity Tests

Toxicity tests range from very short-term acute tests to chronic studies that may last the lifetime of an animal. Acute toxicity studies involve administration of a single dose to each member of a test group (either at one time or in a cumulative series over a short period of less than 24 hours). Subacute tests last from a few days to 4 weeks. Subchronic toxicity studies, which are used to determine the effects of multiple doses, usually last from 1 to 3 months, but generally less than one-half the life span of the test species. Chronic studies, also used to determine the effects of multiple or continuous doses, normally last 2 years but generally last more than one-half the test species' life span.

### Routes of Administration

Routes of administration include oral by gavage (forced into the stomach with a syringe through plastic tubing) and in the diet, dermal (applied to the skin), inhalation (through exposure to vapors or aerosol particles), and parenteral (injected other than into the intestine). Parenteral routes include subcutaneous (injected under the skin), intraperitoneal (injected into the abdominal cavity), and intravenous (injected into a vein). The selection of the route of administration of a particular test material is based on the probable route of human exposure. Oral, dermal, and inhalation doses most nearly duplicate the likely routes of exposure to humans. Parenteral doses are used in testing drugs but are not widely used in toxicity testing of pesticides because they bypass the test animal's natural protective mechanisms.

A dose is expressed as milligrams of the chemical per kilogram of body weight (mg/kg/body weight) of the test animal, in parts per million (ppm) in the animal's diet, in milligrams per liter (mg/L) in the air that the animal breathes, or in mg/L of the water that the animal drinks. In long-term studies, the test substance is generally administered in the diet with specified amounts in parts per million (ppm). The known weight of the test animal over the test period is used to convert ppm in the diet to milligrams of chemical per kilogram of body weight per day (mg/kg/day) for extrapolation to humans. In most chronic toxicity studies, at least three dosing levels are used in addition to a zero-dose or control group. In general, the control group animals are administered the vehicle (for example, water or saline) used in administering the test material. In a dietary study, the basal feed would serve as the vehicle. At this point, it is helpful to clarify the distinction between exposure and dose. Exposure is the amount of a chemical in the environment available to be taken in; dose is the amount that actually enters the body.

## Types of Toxicity Studies

### Acute Toxicity Studies

Acute toxicity studies are used primarily to determine the toxicity reference level known as the median lethal dose ($LD_{50}$), which is the dose that kills 50 percent of the test animals. The lower the $LD_{50}$, the

greater the toxicity of the chemical. The $LD_{50}$ ranges and toxicity categories used in this risk assessment are those of the EPA classification system, using rat $LD_{50}$s, as shown in table B2-1 (adapted from Walstad and Dost, 1984). Because lethality is the intended toxic endpoint, dose levels usually are set relatively high in acute studies. Toxic symptoms displayed by the animals are recorded throughout the study, and tissues and organs are examined for abnormalities at the end of the test. Rats are most commonly used for oral $LD_{50}$s. Rabbits are used most often to determine dermal $LD_{50}$s.

Because death represents the extreme toxic consequence for judging possible effects from the use of pesticides, the policies of regulating agencies regarding acceptable intake levels of these chemical compounds are not based on acute studies, but rather on toxicity tests designed to find the dose level that produces no effects in the animal species tested. Figure B2-1 illustrates the relationship between the $LD_{50}$ and the no-observed-effect level.

**Table B2-1. Acute Toxicity of the Boll Weevil Control Insecticides and Other Chemicals**

| EPA Toxicity Category and signal words | Chemical substance | Oral $LD_{50}$ for rats (mg/kg) |
|---|---|---|
| IV Very slight | | EPA range: 5,000 to 50,000 |
| | Sugar | 30,000 |
| | Ethyl alcohol | 13,700 |
| | Diflubenzuron | >4,640 |
| III Slight (caution) | | EPA range: 500 to 5,000 |
| | Xylene | 4,300 |
| | Table salt | 3,750 |
| | Bleach | 2,000 |
| | Aspirin, vitamin $B_3$ | 1,700 |
| II Moderate (warning) | | EPA range: 50 to 500 |
| | Malathion | 370 |
| | Caffeine | 200 |
| | Chlorpyrifos | 82 |
| | Propoxur | 70 |
| I Severe (danger—poison) | | EPA range: 0 to 50 |
| | Nicotine | 50 |
| | Azinphos-methyl | 4.4 |
| | Methyl parathion | 3.6 |
| | TCDD (a dioxin) | 0.01 |

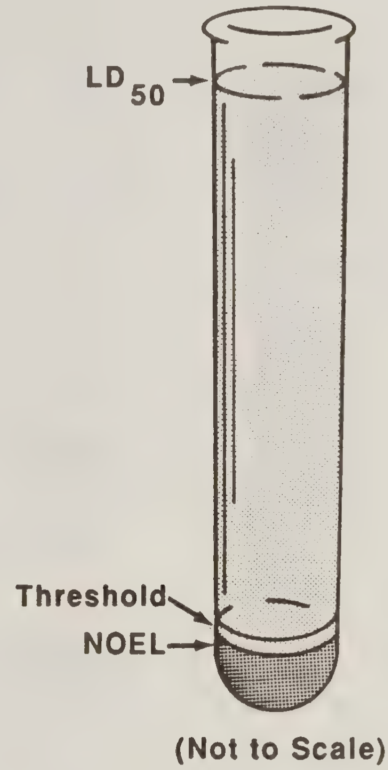
Source: Adapted from Walstad and Dost, 1984.

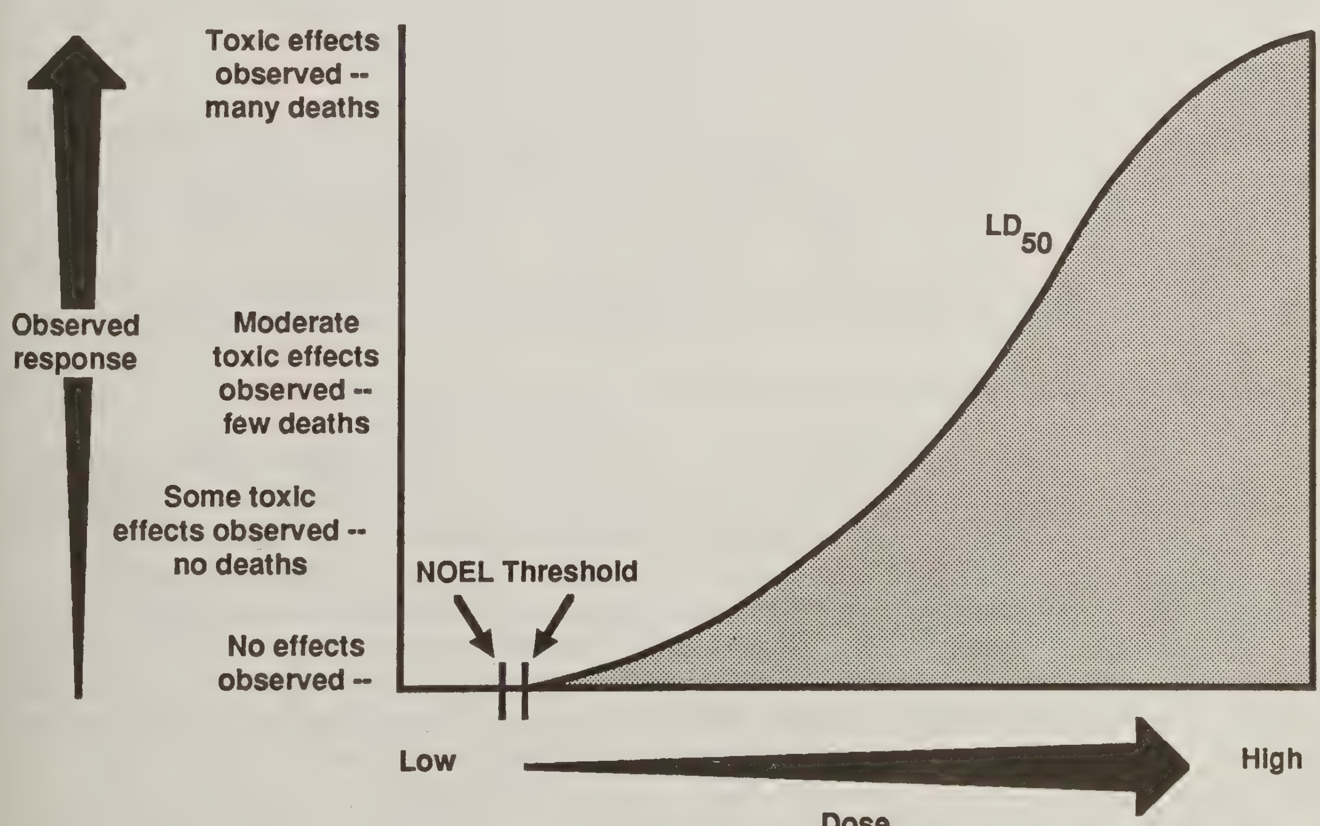
**Figure B2-1. Relationships Among Toxicity Reference Levels**

$LD_{50}$ - Acute lethal dose. One-time or short-term dose that is lethal to 50 percent of treated animals.

Threshold - Dose level at which toxic effects are first observed in test animals (LEL).

NOEL - No-observed-effect level. Long-term dose that does not result in apparent adverse effects in test animals.



## Subchronic Toxicity Studies

Subchronic studies are designed to determine the NOEL. If a chemical produces effects at the lowest dose tested in a study, the NOEL must be at some lower dose. If the chemical produces no effects, even at the highest dose tested, the NOEL is equal to or greater than that dose. Another toxic endpoint of interest is the lowest dose showing toxic effects—the lowest effect level (LEL). For local and systemic effects, the chemical's threshold of effect lies between the NOEL and the LEL for the tested species (see fig. B2-1). Subchronic studies, which normally use lower dose levels than acute studies, provide information on systemic effects, hazards to reproductive success, cumulative toxicity, the latency period (the time between exposure and the manifestation of a toxic effect), the reversibility of toxic effects, and appropriate dose ranges for use in chronic tests. The adverse effects may include overt clinical signs of toxicity, reduced food consumption, abnormal body-weight change, abnormal clinical hematology or chemistry, or abnormalities (macroscopic or microscopic) in the tissue of the test organism.

## Chronic Toxicity Studies

Chronic studies, like subchronic studies, can be used to determine systemic NOELs. All other things being equal, the longer the study from which the NOEL is derived, the more reliable the resulting value for estimating effects in humans. Chronic studies, however, are even more important in determining the carcinogenic potential of a chemical. Chronic tests for systemic effects, reproductive effects, and carcinogenicity provide the bulk of data on laboratory animal tests.

## Developmental Studies

Developmental studies (also called teratogenicity studies) determine the potential of a chemical to cause malformations in an embryo or a developing fetus between the time of conception and birth. These studies generally use rats or rabbits, and though the studies are usually short term, they may be conducted over several generations. The animals are monitored for functional and structural deformities.

## Reproduction Studies

Reproduction studies are conducted to determine the effects of a chemical on reproductive success as indicated by fertility (production of germ cells), fetotoxicity (direct toxicity to the developing fetus), maternal toxicity, and survival and weight of offspring. These tests are performed at doses similar to those used in developmental studies, and generally the subjects are rats. Both male and female rats are exposed to the chemical for a number of weeks before mating. The numbers of resulting pregnancies, stillbirths, and live births are recorded. Tests are usually conducted over two or three generations.

## Cancer Studies and Cancer Potency Determination

Oncogenicity studies examine the ability of a chemical to cause cancerous (malignant) or benign (non-malignant) tumors when administered over the animal's lifetime. Testing is normally conducted with rats or mice for approximately 2 years. Often, chronic oral toxicity is also assessed during an oncogenicity study. The cancer potency of a chemical is defined as the increase in likelihood of getting cancer from a unit increase (1 mg/kg/day) in the dose of the chemical. One possible method to determine the risk-dose relationship from animal data is illustrated in figure B2-2. The curve, derived from tumor data generated in laboratory animal studies, estimates the cancer probability for each dose. The dose levels used in laboratory cancer studies are high, although exposures to humans are expected to be low. The curve relating dose to cancer probability approximates a straight line in the low-dose region. The slope of the curve in this region represents the cancer potency. It is assumed that any dose, no matter how small, has some probability of causing cancer. This assumption is embodied in the one-hit model for determining the cancer potency of a chemical.

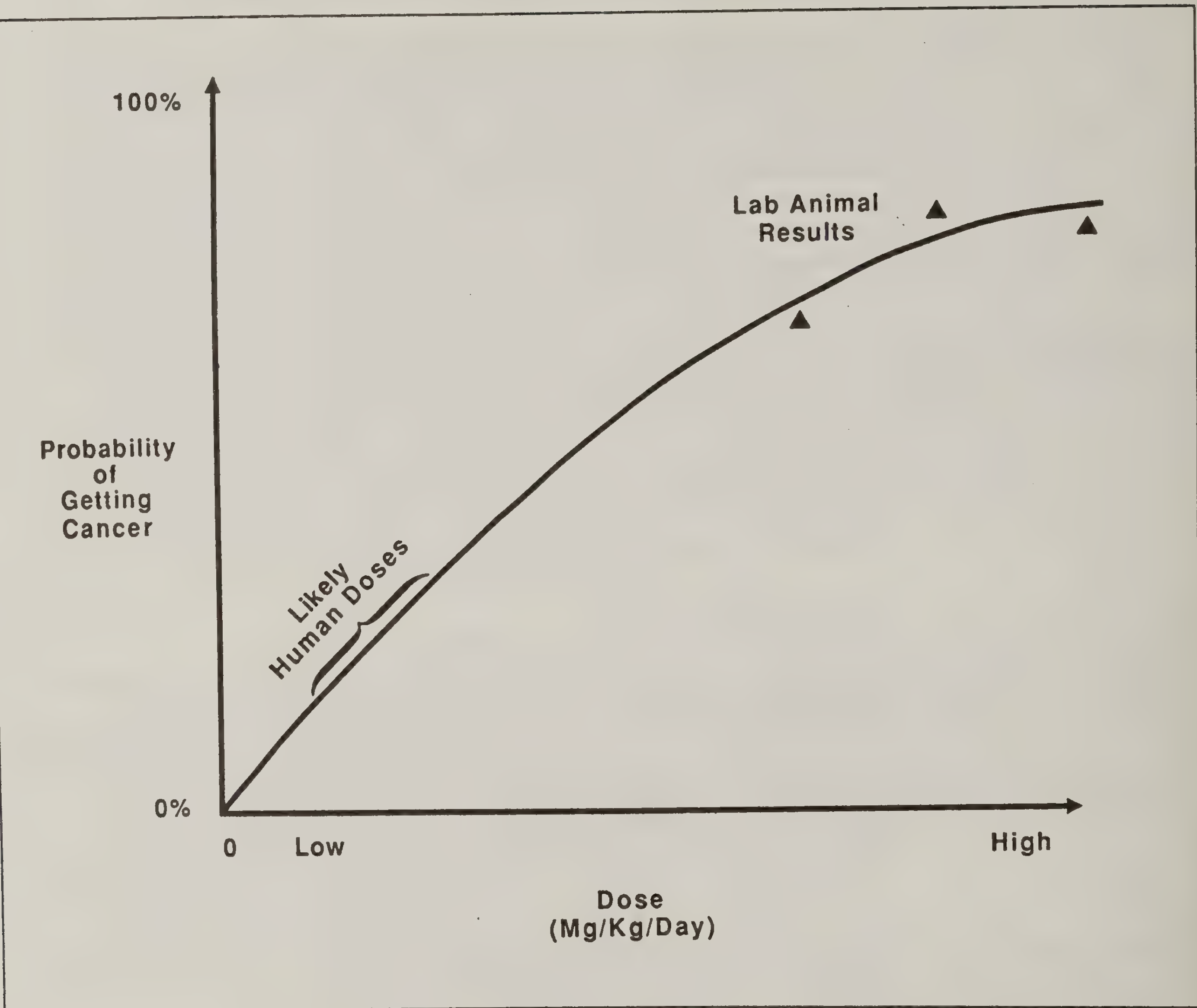
## Mutagenicity Assays

Mutagenicity assays are used to determine the ability of a chemical to cause physical changes, known as mutations, in the basic genetic material deoxyribonucleic acid (DNA), especially changes that could be passed from one generation to the next. The species used in these tests range from primitive organisms, such as the bacteria *Salmonella*, *Escherichia*, and *Streptomyces*; the mold *Aspergillus*; the yeast *Saccharomyces*; and the fruit fly *Drosophila* to the more advanced organisms, including mammals such as mice and rats. Tests may be conducted *in vivo* (within the body of the living organism) or *in vitro* (on cells cultured outside the body in a Petri dish or test tube). Mutagenicity assays can be divided into three categories:

- Tests for detecting gene mutations
- Tests for detecting chromosomal aberrations
- Tests for detecting DNA repair and recombination, a sign of primary DNA damage

Tests used to detect gene mutation include microbial assays involving bacteria, yeasts, fungi, and mammalian cells. Microbial assays are developed to detect reverse mutations (a mutant gene that undergoes mutation back to the wild or normal type) and, to a limited extent, forward mutations (a wild-type gene that undergoes mutation). Many mutagens are inactive before bioactivation by metabolic activity; consequently, many *in vitro* tests include a bioactivation system—such as a liver microsomal (S9 fraction) homogenate from rats or other animals to activate the mutagen. Another mutagenic bioactivation assay is the *in vivo* host-mediated assay. A host-mediated assay is one in which

**Figure B2-2. Cancer Potency Curve**




microorganisms and a potential mutagen are injected into the peritoneal cavity of the host, usually a mouse. The host animal provides a system in which bioactivation of the mutagen against the microorganism can be evaluated, as well as a means of assessing detoxification, systemic distribution, and excretion. Other tests useful for predicting gene mutations are the fruit fly sex-linked recessive lethal test, which measures the frequency of lethal mutations; the mouse specific locus test, which detects mutagenicity in germ cells *in vivo*; and mammalian somatic cell assays *in vitro* using mouse lymphoma cells, human lymphoblasts, and Chinese hamster ovary cells to detect forward and reverse mutations.

Examples of tests that detect chromosomal aberrations are *in vitro* mammalian cytogenetic assays and *in vivo* rodent bone marrow micronucleus or metaphase analyses. The dominant lethal test in rodents,

which determines lethal mutation in germ cells, and the heritable translocation test in mice, which detects the heritability of chromosomal damage, are important tests performed with live animals. Fruit flies and other insects also are used to detect heritable chromosomal effects *in vivo*.

The existence of DNA damage caused by mutagens is detected by biologic processes, such as DNA binding or DNA repair and recombination, that occur after DNA damage. Tests for such processes use bacteria, yeast, and mammalian cells *in vitro*, with and without metabolic activation. For example, many tests use unscheduled DNA synthesis to indicate DNA repair in human cells *in vitro*. Mitotic recombination and gene conversion indicate DNA damage in yeast; sister chromatid exchange indicates DNA damage in mouse lymphoma cells, Chinese hamster ovary cells, and human lymphocytes.

### Epidemiology Studies

The effects on humans of exposure to chemicals in the environment can be derived from *in vivo* or *in vitro* laboratory studies (as described above), reports of clinical observations of isolated exposed people (human poisoning incidents), experimental studies in humans, or from direct observations of exposed human populations. The data on humans generally fall into two categories: (1) clinical data on individuals; and (2) epidemiological data revealing patterns of disease or death in groups of humans exposed to single agents or to a variety of substances.

Thus, epidemiology studies are done to investigate the causes of disease in specified human populations by examining relationships between the incidences of particular disease types and factors associated with the disease, such as uses of particular substances in the workplace. One such association is the use of various pesticides by agricultural workers and the incidence of several types of cancer.

### Epidemiology Studies of Agricultural Workers

A literature search did not reveal any epidemiological information on the insecticides under consideration for the National Boll Weevil Cooperative Control Program. However, data are available on some epidemiological characteristics of pesticides in general.

Studies conducted by the National Cancer Institute (NCI) have found that fewer farmers die from cancer than would be expected, based on the cancer death rate in the general population in the United States. However, farmers have a higher risk of developing lymphatic and blood-related cancers, including leukemia and cancers of the prostate, skin, and stomach (Blair, 1982; Blair et al., 1985; Blair and Thomas, 1979; Blair and White, 1981, 1985; Cantor, 1982; Cantor and Blair, 1984; Weininger et al., 1987).

Although no single agricultural factor has been associated consistently with increased rates of specific cancers, correlations with insecticide and herbicide use have been noted in a number of studies (Blair and White, 1985; Cantor, 1982; Cantor and Blair, 1984; Cantor et al., 1985). In the United States, farmers have a much lower rate of lung cancer than the general population, primarily because of their lower smoking rate (Blair, 1982). However, a cohort study of pesticide-exposed male agricultural workers in the German Democratic Republic (Barthel, 1981) found that they had a significantly higher mortality rate from lung cancer than the general population.

In a study of licensed pesticide applicators in Florida, excess deaths were observed for leukemia and cancers of the brain and lungs (Blair et al., 1983). The risk of lung cancer rose with the number of years licensed (Blair et al., 1983). Other studies have found little or no correlation between cancer incidence and pesticide use (Blair and Thomas, 1979; Blair and White, 1981), although such factors as exposure to oncogenic animal viruses have been related to increases in certain types of cancer (Blair, 1982; Blair et al., 1985).

## Neurotoxicity Studies

Scientists have developed several test procedures to detect neurotoxic effects. For example, neurologic examinations can be performed on animals or humans to help identify the site of adverse effects. These examinations include evaluating responses to sound and light stimuli, testing reflexes, observing gait abnormalities, observing spasticity or tremor, and examining muscles for atrophy, weakness, or fasciculation. Morphologic examinations are pathologic observations of abnormalities or lesions. Delayed neurotoxicity testing involves a single administration of a chemical to hens, which are readily susceptible to this type of neurotoxicity, followed by an examination 8 to 10 days later for signs of distal axonopathy. Electrophysiologic examinations include measurements of conduction velocities and action potentials, electromyography, and electroencephalography. Biochemical examinations can indicate damage to or changes in the enzyme systems in neuronal glucose metabolism, the ion transport systems, protein synthesis, neuronal biochemical composition, and neurotransmitter levels and binding sites. *In vitro* testing on cultured nerve cells can include electrophysiologic, morphologic, or biochemical examinations. Behavioral studies look for changes in conditioned or unconditioned responses in the belief that behavioral changes are a subtle and sensitive indicator of neurotoxicity.

## Immunotoxicity Studies

In general, four types of adverse effects on the immune system are possible as a result of exposure to chemical substances: immunosuppression, uncontrolled proliferation (leukemia and lymphoma), alterations of host defense mechanisms against pathogens and neoplasms, and allergy or autoimmunity. According to Klaassen et al. (1986):

> It is becoming increasingly apparent that the immune system represents an important target organ for studying the toxicology of chemical exposure for the following reasons: immunocompetent cells require continued proliferation and differentiation for self-renewal and are thus sensitive to agents that affect cell proliferation; the cellular and molecular biology of the immune system is better understood than in many other target organ systems, and thus the mechanism(s) by which toxicants are immunoalterative can be determined; functional assessment or enumeration of leukocytes can be easily achieved using a small volume of blood or lymphoid tissue; and finally, observations obtained in experimental animals can be confirmed in humans using leukocytes obtained by minimally invasive methods (i.e., venipuncture).

Many tests are available that incorporate or are targeted primarily at an assessment of the effects of chemicals on the immune system. They include immunocompetence tests *in vivo*, cell-mediated immunity assays *in vivo* or *in vitro*, the plaque assay to evaluate humoral immunity *in vivo*, macrophage and bone marrow assays, hematology profiles, clinical chemistry tests, serum protein studies, organ weight observations, and the histology of immune-related organs.

Allergic hypersensitivity is a particular form of immune system response to a foreign substance. Allergic hypersensitive reactions may be immediate, such as in anaphylactic reactions to insect bites or penicillin injections; or they may be delayed, as in the case of positive responses to tuberculin tests or contact dermatitis caused by poison ivy. Severe, immediate anaphylactic reactions, which can be fatal if not treated promptly, are antigen-antibody reactions that produce sensitivity in individuals. The delayed allergic hypersensitive reactions usually are directed against whole foreign organisms (bacteria, viruses, fungi) but, as in contact dermatitis, may be induced by lower molecular weight substances, such as the catechols of poison ivy, cosmetics, drugs, or antibiotics. Benzocaine, neomycin, formaldehyde, nickel, chromium, and thiram are all known to produce these reactions (Marzulli and Maibach, 1983).

## Acceptable Daily Intake/Reference Dose

Acceptable daily intake levels (ADIs) are values that reflect the combination of knowledge and uncertainty concerning the relative safety of a chemical (NRC, 1977). An ADI is an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily exposure of the human population, including sensitive groups, that is likely to be without an appreciable risk of adverse effects during a lifetime. EPA prefers the term "reference dose" (EPA, 1988a).

The ADI, or reference dose, is selected using the lowest systemic NOEL from the most relevant species. This NOEL is divided by an uncertainty factor, which is usually 100. This includes a factor of 10 to allow for the variation of response within the test species and a factor of 10 to allow for the extrapolation to humans. An additional uncertainty factor of 10 may be applied to account for extrapolation from a shorter term study (a subchronic study). In general, because of the lack of sufficient

human toxicity data, the data obtained from laboratory animal studies are used to determine a reference dose. The critical study is one in which exposure to the toxicant has been carefully controlled and the problems of heterogeneity of the exposed population and concurrent exposures to other toxicants have been minimized. The critical study provides the NOEL used to calculate the ADI, or reference dose. The NOEL used in the ADI, or reference dose, calculation is established in a study that uses an animal model most relevant to humans; however, in the absence of a clearly relevant species, the most sensitive species (the species that exhibited the lowest NOEL) is selected.

The reference dose value is relevant in this discussion of the toxicity of the boll weevil control insecticides because it provides a useful point from which to evaluate the potential effects of a chemical at other doses. In general, doses that are less than the reference dose are unlikely to be associated with health risks. In the case of diflubenzuron, the NOEL used to establish the reference dose is not the systemic NOEL used in this risk assessment but is based on a study that resulted in a lower NOEL. In all other cases, the systemic NOEL used in this risk assessment is equal to the NOEL used in reference dose determination. The reference dose is presented in the human toxicity discussion for each chemical.

## Toxicity Program of Insecticides

The following subsections summarize the most relevant toxicity study data on the proposed boll weevil control program insecticides. The inert ingredient xylene, which makes up 4.9 percent of the Penncap M® methyl parathion formulation, is also discussed.

Acute and chronic toxicity reference levels of the boll weevil control program insecticides are presented in table B2-2. The $LD_{50}$s in table B2-2 are from rat acute oral toxicity studies. (Refer to table B2-1 for toxicity categories.) Rat studies were used because rats are among the most commonly tested animals, and values from rat studies are available for all of the insecticides.

Two types of NOELs are given in table B2-2. The first is for general systemic effects (for example, growth retardation, decreased red blood cell count, and increased thyroid weight). The systemic NOELs used in this risk analysis are taken from chronic feeding studies in laboratory animals and studies of human volunteers. The second NOEL is for reproductive and developmental effects, including infertility, miscarriage, general fetal toxicity, and birth defects (teratogenesis). All the NOELs identified represent the most sensitive toxicity response found in evaluated studies.

Table B2-3 summarizes the carcinogenic and mutagenic properties of the insecticides. A discussion of existing data gaps identified by EPA is presented after the toxicity discussion for each insecticide.

**Table B2-2. Acute and Chronic Toxicity Reference Levels Used in This Analysis**

| Insecticide | Acute oral $LD_{50}$ in rats (mg/kg) | Systemic NOEL (mg/kg/day) | | Reproductive/ developmental NOEL (mg/kg/day) |
|---|---|---|---|---|
| | | Human | Rat | |
| Malathion | 370 | 0.23 | 5.0 | 25 |
| Azinphos-methyl | 4.4 | 0.286 | 0.125 | 2.5 |
| Diflubenzuron | >4,640 | NA | 1.0[a] | >8.0[b] |
| Methyl parathion | 3.6 | 0.31 | 0.025 | 0.25 |
| Chlorpyrifos | 82 | 0.03 | 0.03[a] | 0.8 |
| Propoxur | 70 | 0.36[c] | 5.0[a] | 12.5 |
| Xylene (inert) | 4,300 | NA | 179.0 | 0.3 |

[a] This systemic NOEL is determined from a chronic dog study.
[b] This NOEL is the highest dose tested; thus it may overstate risks of reproductive effects.
[c] This value is not a NOEL; however, EPA based its reference dose on this study, with an uncertainty factor of 100.

Note: NA = Not available.

## Principal Toxic Effects of Organophosphate and Carbamate Pesticides

Of the insecticides considered for use, four are organophosphates and one is a carbamate. The following discussion is a general overview of the toxicities of organophosphate and carbamate compounds as found in Smith (1987); Cranmer (1986); and Klaassen et al. (1986). This information does not apply to diflubenzuron, which is a chitin pathway inhibitor.

Organophosphates such as malathion, methyl parathion, azinphos-methyl, and chlorpyrifos or carbamates such as propoxur inhibit the cholinesterase (ChE) enzyme acetylcholinesterase, which is responsible for the breakdown of acetylcholine. Acetylcholine is a neurotransmitter that permits the transmission of nerve impulses across the nerve synapse. Acetylcholinesterase inhibition results in accumulation of acetylcholine and the continual transmission of nerve impulses. ChE inhibition caused by a given dose of an organophosphate usually lasts longer than inhibition caused by a carbamate at a given dose level. Additionally, the effects of organophosphates tend to accumulate, so a sequence of low doses can produce the same effect as a single higher dose. Organophosphates exhibit an irreversible pesticide-enzyme binding reaction. In contrast, the carbamylated enzyme (formed in reaction with carbamate pesticides) is destabilized through biochemical processes in the body. Carbamates are relatively rapid reversible ChE inhibitors. Generally, organophosphates partially metabolize to more active ChE inhibitors, for example, malathion to malaoxon. Carbamates, however, appear to function unaltered as inhibitors.

**Table B2-3. Carcinogenic and Mutagenic Properties of Insecticides**

| Chemical | Carcinogenicity | Mutagenicity[a] |
|---|---|---|
| Malathion | Two negative rat studies; one inconclusive study in mice; metabolite malaoxon had equivocal results in a rat study; cancer potency = 0.02 $(mg/kg/day)^{-1}$; EPA class D[b] | One positive cytogenetic analysis and one positive test for sister chromatid exchange |
| Azinphos-methyl | Two negative studies in mouse; one inconclusive study in rats; cancer potency = 0.00376 $(mg/kg/day)^{-1}$; EPA class D[b] | Some positive studies for gene mutation, chromosomal effects, and unscheduled DNA synthesis |
| Diflubenzuron | Negative rat and mouse studies; previous mouse study suggested oncogenic response; cancer potency = 0.01718 $(mg/kg/day)^{-1}$; EPA class D[b] | One positive test for gene mutation and one positive cytogenetic analysis |
| Chlorpyrifos | One negative mouse study and one negative rat study; EPA class D[b] | Positive test for direct DNA damage and weakly positive for mitotic recombination |
| Methyl parathion | 3 negative studies (2 rat, 1 mouse); inconclusive rat study; insufficient data to quantify cancer potency; EPA class D[b] | EPA considers it mutagenic and genotoxic; many positive studies |
| Propoxur | Positive rat study and negative mouse study; cancer potency = 0.00079 $(mg/kg/day)^{-1}$; EPA class B2[c], C[d] | Some positive results for gene mutation, chromosomal aberrations, and unscheduled DNA synthesis |
| Xylene | No data; EPA class D[b] | No positive studies reported |

[a] Only results of positive studies are noted. See the text for more information.
[b] EPA class D = not classifiable as to human carcinogenicity.
[c] EPA class B2 = probable human carcinogen (Toxicology Branch).
[d] EPA class C = possible human carcinogen (Carcinogen Assessment Group).

The toxic effects of ChE inhibition at low doses in humans include localized effects such as nosebleed, blurred vision, and bronchial constriction, as well as systemic effects such as nausea, sweating, dizziness, and muscular weakness. Effects of higher doses include irregular heartbeat, elevated blood pressure, cramps, and convulsions. In general, ChE inhibition up to 40 percent (40-percent reduction in activity) in laboratory animals and humans is tolerated well and may produce transitory, less severe symptoms. However, in most studies, 20-percent inhibition is considered significant. This occurs when plasma, erythrocyte, or brain ChE activity decreases 20 percent as a result of treatment. Inhibition of ChE activity above 50 percent can lead to much more severe or prolonged symptoms. When a fatal dose of organophosphate or carbamate has been received without emergency treatment (generally administration of the antidote atropine), death usually occurs within 24 hours.

In addition to ChE inhibition, other toxic effects of organophosphates include delayed neurotoxic effects of phosphate triesters such as nerve cell demyelination and slow, but generally reversible, weakness and flaccidity of the limbs.

**Malathion**

At high doses, malathion may cause symptoms associated with ChE inhibition, including headache, nausea, weakness, and muscular twitching, but it has not demonstrated other neurotoxic effects. No developmental effects were observed in laboratory animal reproduction studies. Carcinogenicity testing has resulted in equivocal findings. Malathion's mutagenic potential cannot be determined. It may act as a contact sensitizer and is potentially immunotoxic. Malathion has demonstrated synergistic responses when mixed with other chemicals, especially other organophosphates.

### General and Systemic Toxicity

***Human Toxicity.*** A 7-week feeding study in humans determined a NOEL of 0.23 mg/kg/day, and an LEL of 0.34 mg/kg/day for blood ChE inhibition (EPA, 1988b). This value is the systemic NOEL for malathion in this risk assessment and is the basis for EPA's reference dose for malathion. According to Hayes (1982a), a single oral dose of 58 milligrams (mg) malathion (0.84 mg/kg of body weight) did not produce any clinical effects. However, according to the same source, fatal human poisoning has been reported for doses as low as 56 mg/kg of body weight. The human skin appears to provide an effective barrier to absorption of malathion. When $^{14}$C-labeled malathion was applied to the ventral forearm of human volunteers, an average of between 4.5 and 8.2 percent of the total dermal dose was recovered in the urine during the first 5 days (Wester et al., 1983). A 42-day inhalation study in humans did not show any ChE inhibition at the highest dose tested of 2.4 grams/1,000 $ft^3$ (0.0848 milligrams per liter (mg/L)) (EPA, 1988b). Metabolism and excretion of malathion in humans appear to be prompt. A single dose of 25 mg administered to each of

six male volunteers was completely metabolized within 8 hours. Elimination was mainly in the urine (Hayes, 1982a).

Symptoms of malathion intoxication in humans include tightness of the chest, wheezing, cyanosis, pupil constriction, aching in and behind the eyes, blurred vision, tearing, runny nose, headache, and salivation following inhalation exposure; loss of appetite, nausea, vomiting, abdominal cramps, and diarrhea following oral ingestion; and sweating and localized twitching after dermal exposure. High doses through any exposure route may lead to weakness, generalized twitching, paralysis, dizziness, confusion, staggering, slurred speech, irregular or depressed heart rate, convulsions, respiratory failure, coma, and death (NLM, 1988).

A reference dose of 0.02 mg/kg/day is recommended by EPA and the World Health Organization (EPA, 1988c), based on the 7-week study in humans discussed previously. The Occupational Safety and Health Administration (OSHA) has promulgated a standard of 15 $mg/m^3$ (0.015 mg/L) air concentration as a time-weighted average (National Institute of Occupational Safety and Health (NIOSH), 1987); the Federal Mine Safety and Health Act of 1977 set a standard of 10 $mg/m^3$ (0.010 mg/L), also a time-weighted average (NIOSH, 1987).

***Acute and Subacute Toxicity to Laboratory Animals.*** Acute oral $LD_{50}$s in rats have been reported to be 1,945 mg/kg (EPA, 1988d) and as high as 2,800 mg/kg (American Cyanamid, 1986) and 5,500 mg/kg (EPA, 1987a). An acute $LD_{50}$ of 370 mg/kg was reported from an intraperitoneal injection study; this is the reference level used in this risk assessment.

Acute dermal $LD_{50}$ values are 4,100 mg/kg in rabbits (American Cyanamid, 1986) and 4,444 mg/kg in rats (NIOSH, 1987). Two primary dermal irritation studies in rabbits led EPA (1987a) to consider malathion a slight irritant.

Malathion is considered to be a mild eye irritant (EPA, 1988d). Three primary eye irritation studies were reported by EPA (1987a). The first two studies showed no irritation, while the third study resulted in a mild conjunctival reaction that was reversible within 7 days.

An acute inhalation median lethal concentration ($LC_{50}$) value in laboratory animals has not been defined. Three studies determined that the $LC_{50}$ is greater than the doses tested, which were 1.7 mg/L, 4.0 mg/L, and 5.2 mg/L (EPA, 1987a).

***Chronic and Subchronic Toxicity to Laboratory Animals.*** The lowest NOEL determined in a laboratory animal study was 100 ppm (5 mg/kg/day) in a 2-year rat study, with significantly depressed plasma, brain, and erythrocyte cholinesterase noted at the LEL of

1,000 ppm (50 mg/kg/day) (EPA, 1988b). Another chronic rat toxicity test also determined a NOEL of 100 ppm (5 mg/kg/day), with significantly depressed body weights and brain cholinesterase levels observed at a dose of 1,000 ppm (50 mg/kg/day) (EPA, 1988b).

A 1-year oral toxicity study in dogs resulted in a NOEL of less than 62.5 mg/kg/day, the lowest dose tested. Adverse effects at 62.5 mg/kg/day included erythrocyte and plasma cholinesterase inhibition; elevated liver, kidney, and thyroid/parathyroid gland weights; elevated platelet count; and reduced liver enzyme levels (EPA, 1988b).

Subchronic toxicity studies with malathion include a 32-day oral rat study with a NOEL of 100 ppm (5 mg/kg/day) and an 8-week oral rat toxicity study with a NOEL of 500 ppm (25 mg/kg/day), the highest dose tested (EPA, 1988b).

### Reproductive/Developmental Toxicity

A rabbit teratology study (EPA, 1988d) was used to set the reproductive/developmental toxicity reference level used in this risk assessment. The NOEL in this study was 25 mg/kg/day (the reference level used in this assessment); at the LEL of 50 mg/kg/day, decreases in maternal body-weight gain and increases in mean percent of resorptions were observed. In another teratology study, a single intraperitoneal injection of 900 mg/kg/body weight did not result in any reproductive or developmental effects in pregnant Sherman rats (EPA, 1988a). In a third teratology study, Khera et al. (1978) reported no teratogenic effects at 300 mg/kg, the highest dose tested, when technical malathion (the active ingredient as manufactured) was administered to rats by gastric intubation during gestation.

In a two-generation reproduction study (Kalow and Marton, 1961), technical malathion was fed to Wistar rats at a dietary concentration of 4,000 ppm (240 mg/kg/day). Male and female rats were bred after 10 weeks. Survival of the progeny after birth was found to be reduced, and the surviving offspring showed growth retardation.

### Carcinogenicity

The oncogenic potential of malathion and its metabolite malaoxon has been evaluated based on three bioassays that EPA reviewed. An 80-week bioassay of mice and rats exposed to malathion did not show increased tumor incidence (NCI, 1978). EPA (1988d) questioned the negative conclusion with respect to mice, based on study design flaws and questionable liver findings. A second bioassay during which rats were administered 2,000 or 4,000 ppm (50 or 100 mg/kg/day) for 103 weeks did not result in evidence of carcinogenicity. EPA classifies malathion as a class D carcinogen, meaning there is insufficient evidence to classify its human carcinogenic potential.

A review by the National Toxicology Program (NTP) reevaluated studies on the carcinogenicity of malathion and its metabolite malaoxon (Huff et al., 1985). The review confirmed the original conclusion of the National Cancer Institute (NCI) that malathion was noncarcinogenic. However, NTP concluded that there was equivocal evidence of carcinogenicity for male and female rats for malaoxon because of C-cell neoplasms of the thyroid gland. Consequently, theoretical lifetime cancer risks were calculated for malathion to estimate the maximum possible risk of cancer. A cancer potency estimate of 0.00376 $(mg/kg/day)^{-1}$ was calculated, based on use of the linearized multistage model and tumor data reported for the NCI mouse study by the California Department of Health Services (1980).

### Mutagenicity

EPA (1988d) is requiring further studies before determining the mutagenic potential of malathion. A 1976 cytogenetic study in rats reviewed by EPA (1988b) showed that administration of 20 mg/kg/day on the 4th through 23rd days of life caused a slight reduction of spermatogenic (sperm-producing) cells and Leydig cells. The authors assumed that testosterone synthesis was reduced, followed by damage to spermatogenic cells. They also stated that all parameters had returned to normal by the 50th day of life (Krause et al., 1976).

According to the International Agency for Research on Cancer (1983), malathion was negative for mutagenicity in most studies of bacteria, including the Ames gene mutation assay and in two studies using yeast. It was negative in a *Drosophila melanogaster* assay for sex-linked lethal mutations. Malathion increased sister chromatid exchange frequency in cultured mammalian cells and in mice treated *in vivo*. Dominant lethal tests in mice and a test for unscheduled DNA synthesis were negative. Two other studies reviewed by EPA (1988b)—recombination and reversion assays—were both negative.

### Neurotoxicity

Malathion was negative in a delayed neurotoxicity test in hens (EPA, 1988b). Like most other organophosphate compounds, malathion inhibits acetylcholinesterase, as discussed previously. According to Klaassen et al. (1986), malathion has not been shown to cause other neuropathies (abnormalities in nerve cells) in any tested species.

### Immunotoxicity

Milby and Epstein (1964) reported that malathion may act as a contact sensitizer capable of causing contact dermatitis under field-use conditions. Malathion was shown to be a sensitizer in guinea pigs by intradermal injections and topical applications, but not by a Draize dermal irritation procedure (Magnasson and Kligman, 1970; as cited in Cushman and Street, 1983). However, EPA (1988d) reported that results of acceptable studies show that malathion is nonsensitizing by

the dermal route. Vijay et al. (1978; as cited in Klaassen et al., 1986) found that rats injected with malathion developed IgE reaginic antibodies, but not IgG antibodies. Desi et al. (1978; as cited in Klaassen et al., 1986) found that exposure to malathion depressed antibody responses in rabbits to *Salmonella typhimurium*.

### Synergistic Effects

Of the numerous organophosphate insecticides, malathion has been observed most frequently as one constituent of a potentiating pair. Synergism with malathion has been reported for EPN, carbaryl (Sevin®), ruelene, phosalone (Zolone®), Abate®, trichlorfon (Dylox®), baycarb (Bassa®), TOCP, and possibly methoxychlor (DMDT) (NLM, 1988). Costa and Murphy (1983) reported that, in mice dosed with disulfoton at 10 mg/kg/day by intraperitoneal injection for 14 days, an intraperitoneal injection of 2,000 mg/kg malathion caused 100 percent mortality (10/10), as compared to 60 percent (6/10) mortality in a control group that had not been previously dosed with disulfoton.

In a study conducted by Keplinger and Deichmann (1967), rats dosed with a combination of toxaphene (Attac®) and malathion had an $LD_{50}$ of 820 mg/kg, whereas the expected $LD_{50}$ from an additive interaction was calculated to be 1,000 mg/kg; rats dosed with a combination of malathion and carbaryl (Sevin®) had an $LD_{50}$ of 221 mg/kg, where the expected additive $LD_{50}$ was calculated to be 403 mg/kg. Several combinations of three insecticides were also studied by the same authors, who observed that malathion in combination with chlordane (Kypchlor) and parathion (Phoskil®), with chlordane (Kypchlor) and toxaphene (Attac®), or with aldrin (Temik®) and chlordane (Kypchlor) has a greater than additive toxicity. Malathion has also been shown to be synergistic with two of the impurities it contains, TMPD and isomalathion (NLM, 1988).

Medaka fish embryos were studied under 25 different concentrations of carbaryl (between 1 to 5.0 ppm) and malathion (0 to 20 ppm). The pair of insecticides produced little more than an additive effect. The exception was found at the highest concentrations for both chemicals, which gave an antagonistic effect (Solomon and Oarker, 1979). The toxicity of malathion given to mice with sublethal doses of parathion, methyl parathion, or fenitrothion indicated all were substantial potentiators of malathion toxicity. Parathion was found to cause an exponential increase in malathion toxicity with higher sublethal doses. Higher quantities of methyl parathion and fenitrothion were required to achieve the same degree of potentiation (Ramakrishna and Ramachandran, 1978).

### Evaluation of Data Base

Of the toxicology studies required by EPA (1988d) for the registration of malathion, the following have not yet been reported as received and reviewed by EPA: an acute delayed neurotoxicity test in hens; a 21-day

dermal irritation test in rabbits; a 90-day rat inhalation study; chronic toxicity studies in rodent and nonrodent species; rat and mouse oncogenicity studies; rat teratogenicity and two-generation reproduction studies; tests for gene mutation, structural chromosomal changes, and other genotoxic effects; oncogenicity studies on malaoxon; and domestic animal safety testing.

Although all the studies EPA requires for reregistration of malathion have not yet been submitted, sufficient information is available from EPA-reviewed studies or in the literature to conduct a quantitative risk assessment. Older studies were used to evaluate neurotoxicity, dermal irritation, chronic toxicity, and effects on reproduction. Doses tested in available inhalation studies in humans and in rodents showed no effects at the highest doses tested, so these levels are considered safe, even though no threshold has been determined. A rabbit teratology study was available for assessing developmental effects. Because previously conducted studies contain uncertainty about the carcinogenic potential of malathion, to be conservative, a cancer risk analysis was conducted. The mutagenic potential of malathion was assessed using studies from the literature.

## Azinphos-methyl

High doses of azinphos-methyl may cause the symptoms associated with cholinesterase (ChE) inhibition, including muscular twitching, headache, nausea, and weakness. No effects on fetal development were demonstrated in laboratory animal studies. One study suggested a potential for carcinogenicity. Several positive effects from mutagenicity studies have been reported, including gene mutation, chromosomal breakage, chromosomal aberrations in cytogenetic analyses, and unscheduled DNA synthesis. Azinphos-methyl may be neurotoxic and has demonstrated immunotoxic action. It is synergistic in combination with trichlorfon and pyrethroids.

### General and Systemic Toxicity

***Human Toxicity.*** The toxic mechanism of action of azinphos-methyl is ChE inhibition. Adverse effects from exposure to toxic levels can include nausea, sweating, tightness in the chest, pupil constriction, stomach pains, vomiting, diarrhea, muscular tremors, uncontrolled mucus secretion, convulsions, and coma (Mobay, 1985).

Human volunteers ingested doses of azinphos-methyl for 30 days with no significant effects on ChE or other clinical changes observed at any level in this study (Hayes, 1982a). The highest dose tested was 20 mg/person/day, equivalent to 0.286 mg/kg/day for an average 70-kg person.

EPA has reviewed three subchronic ChE inhibition studies in humans. All were negative for plasma and erythrocyte ChE inhibition at the highest doses tested of 1.5, 3.5, and 6.0 mg/azinphos-methyl/day, equivalent to 0.02, 0.05, and 0.086 mg/kg/day for an average 70-kg person (EPA, 1988e).

The EPA Office of Pesticide Programs' reference dose for azinphos-methyl is 0.0013 mg/kg/day (EPA, 1988c), based on the same 2-year dog feeding study used to set the systemic NOEL in this risk assessment (see the discussion of chronic toxicity). The acceptable daily intake for humans specified by the World Health Organization (WHO) is 0.0025 mg/kg/day (EPA, 1988c). The American Conference of Governmental and Industrial Hygienists (ACGIH) recommends an inhalation threshold limit value (TLV) of 0.0002 mg/L as a time-weighted average and 0.0006 mg/L as a short-term (15-minute) exposure limit (NIOSH, 1987).

***Acute and Subacute Toxicity to Laboratory Animals.*** The acute oral $LD_{50}$ for technical azinphos-methyl for male and female rats is 4.6 mg/kg and 4.4 mg/kg, respectively (4.4 is the reference level used in this risk assessment) (EPA, 1986a). The Guthion® 2L formulation is reported to result in an oral $LD_{50}$ in rats of 38 mg/kg (Mobay, 1984). The Guthion® 2S formulation has reported oral $LD_{50}$s of 37 and 21 mg/kg for male and female rats, respectively (Mobay, 1984). A 6-day study determined that 3.6 mg/kg/day taken orally was fatal to 5 of the 12 cows tested (EPA, 1988e).

Acute dermal $LD_{50}$ values for technical azinphos-methyl for rats are 155 mg/kg for females and in the range of 200 to 250 mg/kg for males (EPA, 1986a). The mouse dermal $LD_{50}$ has been reported to be 65 mg/kg (NIOSH, 1987). The Guthion® 2L formulation has an $LD_{50}$ of about 350 mg/kg in female rats, and the Guthion® 2S formulation has dermal $LD_{50}$s of 504 and 568 mg/kg in male and female rats, respectively (Mobay, 1984).

The inhalation $LC_{50}$ in rats is 0.069 mg/L for 1 hour, according to NIOSH (1987). Other studies in rats have reported the inhalation $LC_{50}$ to be 6.4 and 23 mg/L for female and male rats, respectively, for an unspecified period of exposure (Chemagro, 1974).

***Chronic and Subchronic Toxicity to Laboratory Animals.*** A 2-year dog feeding study resulted in the NOEL used in this risk assessment of 5 ppm (0.125 mg/kg/day) (EPA, 1986a). This is also the study that EPA used for its reference dose. At higher doses, muscle tremors, drooping of the head, and staggering were observed. A 3-month dog feeding study also showed no effects at 5 ppm (0.125 mg/kg/day) (EPA, 1988e). No NOEL was determined in a 19-week dog feeding study in which ChE inhibition was observed at 20 ppm, the lowest dose tested (0.5 mg/kg/day) (EPA, 1988e).

A 2-year rat feeding study determined a NOEL of 5 ppm (0.25 mg/kg/day), based on ChE inhibition (EPA, 1988e); the LEL was 20 ppm (0.5 mg/kg/day), where a concentration-dependent decrease in ChE activity was demonstrated. Another 2-year rat feeding study yielded a higher NOEL of 50 ppm (2.5 mg/kg/day) (NLM, 1988). At 100 ppm (5 mg/kg/day), the LEL in this study, azinphos-methyl,

caused convulsive episodes and decreases in plasma and erythrocyte ChE activity.

A 4-month rat feeding study demonstrated that decreased body weight; decreased serum, brain, erythrocyte, and submaxillary ChE; and mortality may occur at a dose level of 50 ppm (2.5 mg/kg/day) for 16 weeks (EPA, 1988e). A 28-day rat feeding study showed ChE inhibition at doses higher than 5 ppm (0.25 mg/kg/day) (EPA, 1988e).

A dermal rat study resulted in decreases in body, liver, thymus, and adrenal weights and decreased growth when a dermal dose of 50 mg/kg/body weight of technical azinphos-methyl was applied 5 days per week for 3 weeks (EPA, 1988e). In another study in rats, dermal application of 22 percent azinphos-methyl 5 days per week for 3 weeks resulted in a 30-percent decrease in brain ChE but no hematologic changes at 120 mg/kg/day (EPA, 1988e).

A 3-month inhalation study in rats resulted in a NOEL of 0.00124 mg/L when exposed 6 hours per day, 5 days per week. Higher doses caused ChE inhibition and decreased body weight (EPA, 1988e).

### Reproductive/Developmental Toxicity

No developmental effects have been observed at the highest dose tested in any azinphos-methyl study. However, maternal and fetotoxic effects were observed at the high dose in a rat teratology study (EPA, 1988e), including maternal weight loss, reduced pup weight, and decreased weanling survival. There were no teratogenic effects at 5.0 mg/kg/day, the highest dose tested. The NOEL in this study was 2.5 mg/kg/day, which is the reference level used in this risk assessment. Another rat teratology study showed no maternal toxic, fetotoxic, or developmental effects at 2.0 mg/kg/day, the highest dose tested (EPA, 1988e). Several other reproductive studies in rats showed effects on viability, weaning, growth, and the central nervous system at doses ranging from 0.2 to 5.0 mg/kg/day (NIOSH, 1987). Three rabbit teratology studies reviewed by EPA did not result in developmental effects at any level. In two of these studies, the highest dose tested was 0.75 mg/kg/day; in the third, it was 3.0 mg/kg/day (EPA, 1988e). A mouse teratology study showed no effects at 5.0 mg/kg/day, the highest dose tested (EPA, 1988e). In a study in mice, administration of 16 mg/kg on the 8th day of gestation caused developmental abnormalities of the musculoskeletal system, while 20 mg/kg was fetotoxic (NIOSH, 1987).

A three-generation reproduction study in mice determined a reproductive NOEL of 25 ppm (3.75 mg/kg/day). At 50 ppm (7.5 mg/kg/day), the LEL in this study, there was an unspecified reduced lactation index (EPA, 1988e). A two-generation rat reproduction study determined a NOEL of 15 ppm (0.75 mg/kg/day), based on increased mortality in dams and pups, reduced litter weights and maternal body weights, and clinical signs of ChE inhibition (EPA, 1988e).

## Carcinogenicity

Currently, EPA classifies azinphos-methyl as class D (EPA, 1988c), meaning that its human carcinogenic potential is not classifiable. Class D is generally used for agents with inadequate human and animal evidence of carcinogenicity or those for which no data are available (EPA, 1986b).

A mouse oncogenicity study, conducted by Mobay Chemical Corporation, indicated no statistically significant increase in tumor incidence upon preliminary review by EPA (1986a). A previous mouse study conducted by the NCI demonstrated that no incidence of tumors could be attributed to azinphos-methyl exposure (EPA, 1986a). An 80-week rat oncogenicity study conducted by the NCI concurrently with their mouse study suggested neoplasms of the thyroid gland and of the pancreas; but according to EPA (1986a), the study did not provide sufficient evidence to conclude that azinphos-methyl is oncogenic in rats. EPA has requested another rat oncogenicity study because of deficiencies in the use of the control group. Because one study suggested the possibility that azinphos-methyl could cause cancer, a worst case assumption was made for the purposes of this EIS that azinphos-methyl is carcinogenic. Using the multistage model and the data from the NCI rat study, a cancer potency value of 0.00039 $(mg/kg/day)^{-1}$ was calculated (according to David Ritter, Toxicologist, Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency; personal communication, December 1988).

## Mutagenicity

***Gene Mutation.*** Azinphos-methyl (88.8 percent) did not induce reverse mutation in the bacterium *Salmonella typhimurium* at levels up to 4,000 micrograms per plate (µg/plate), either with or without metabolic activation (EPA, 1988e). In two separate studies on *Schizosaccharomyces pombe* reported in NIOSH (1987), positive results were obtained at 25 millimoles/L. One study did not include activation; the presence or absence of activation was not specified in the other study. Gene mutation studies are conducted at the maximum tolerated dose of the chemical for the test organism.

***Chromosomal Effects.*** An *in vitro* cytogenetic test using human lymphocytes showed that 500 micrograms per milliliter (µg/mL) of 91.9 percent technical-grade azinphos-methyl medium induced chromosomal breaks when activated with the S9 fraction of rat liver homogenate (EPA, 1988e). Three cytogenetic analyses were positive for chromosomal effects in hamster ovary cells, human lung cells, and unspecified human cells at 60, 120, and 140 mg/L, respectively (NIOSH, 1987). For chromosomal effects, positive effects with low doses indicate strong mutagenic potential.

***DNA Repair and Recombination.*** A 91.1-percent azinphos-methyl solution (dose not specified) was negative for unscheduled DNA

synthesis in one study reviewed and was found acceptable by EPA (1988e). In another study, however, unscheduled DNA synthesis was induced in human fibroblast cells at an azinphos-methyl concentration of 10 micromoles (μmol)/L (equal to 3.17 mg/L) (NIOSH, 1987). There was no increase in sister chromatid exchange frequencies in hamster V79 cells at the (unspecified) doses tested in another study (NLM, 1988). For DNA repair and recombination, positive effects with low doses indicate strong mutagenic potential.

### Neurotoxicity

As is characteristic of organophosphate insecticides, azinphos-methyl is a ChE inhibitor, though this inhibition is reversible (Klaassen et al., 1986). Several smaller doses over a relatively short time may be somewhat cumulative as to the extent of ChE inhibition if successive exposures occur before complete reversal has occurred. One study in which rats were dosed with 5/8 of their $LD_{50}$ determined that it took 30 minutes for inhibition to peak and 24 hours for complete reversal (Klaassen et al., 1986). Central nervous system symptoms characteristic of organophosphates include nervousness, apprehension, ataxia, convulsions, coma, and death resulting from respiratory failure or cardiac arrest (NLM, 1988).

Three neurotoxicity studies in chickens have been reviewed by EPA (1988e). A 30-day study resulted in a NOEL greater than 100 ppm (17.5 mg/kg/day), which was the highest dose tested. Another 30-day study gave a NOEL greater than 1,800 ppm (315 mg/kg/day, the highest dose tested), although there was a general deterioration in the condition of the animal. The third chicken neurotoxicity study resulted in a NOEL of 1,800 (315 mg/kg/day), based on a histologic examination of the nerve tissue.

### Immunotoxicity

A 1983 study (Vos et al., 1983) determined that azinphos-methyl had a marked effect on the immune system. Six rats per dose group received dietary doses of 5, 25, or 125 mg of 85 percent technical azinphos-methyl per kg of feed. Only the 125 mg/kg dietary azinphos-methyl dose (6.25 mg/kg/body weight/day) resulted in decreased relative spleen, pituitary, and mesenteric lymph node weights and alterations in the histopathology of the thymus, pituitary, adrenals, and testes. Although a study by Abrahamsen and Jerkofsky (1983) revealed that azinphos-methyl did not enhance the *Varicella zoster* virus, a later study by Krzystyniak et al. (1987) showed that virus-induced cytolysis by mouse hepatitis virus 3 was significantly increased in macrophage cultures after a single azinphos-methyl dose.

### Synergistic Effects

According to Berisford et al. (1985), the combination of azinphos-methyl and trichlorfon (Dylox®) is synergistic. The expected $LD_{50}$ in rats for a

96:3.5-percent mixture of trichlorfon (Dylox®) and azinphos-methyl, respectively, is 82.8 mg/kg if additive toxicity is present. However, a study reported in Berisford et al. (1985) showed that the $LD_{50}$ was lowered to 55 mg/kg.

According to NLM (1988), azinphos-methyl and synthetic pyrethroids form a synergistic mixture. The combination of azinphos-methyl and ethanomethrin has also been reported to be mildly synergistic (Lambert, 1985). Dose levels were not reported in either case.

### Evaluation of Data Base

For a pesticide product to be registered or reregistered under FIFRA, specific studies must be conducted and the results submitted to EPA. EPA (1986a) listed the studies required for reregistration of azinphos-methyl. According to the summary of studies received in support of reregistration (EPA, 1988b) and the reference dose tracking report (EPA, 1988c), the following have not yet been reported as received and reviewed by EPA: a delayed neurotoxicity study in hens, a chronic rodent toxicity study, a rat oncogenicity study, and a rabbit teratogenicity study.

Although all the studies required by EPA for reregistration of azinphos-methyl have not yet been submitted, sufficient information is available from studies that EPA has reviewed and from studies in the literature to conduct a quantitative risk assessment. Neurotoxicity was evaluated using the results of existing studies in chickens. Chronic toxicity testing in dogs was used to establish the systemic NOEL. Because inconclusive results were obtained from at least one study, a conservative assumption was made in this risk assessment that azinphos-methyl may have carcinogenic potential. Teratogenicity was evaluated using existing studies.

## Diflubenzuron

Diflubenzuron causes formation of methemoglobin and sulfhemoglobin in the blood, which reduce the oxygen supply to tissues. No reproductive or developmental effects have been reported. A feeding study in mice suggested evidence of a carcinogenic response, but EPA has determined that there is insufficient evidence to determine the carcinogenic potential of diflubenzuron (EPA, 1987). Most mutagenicity studies have been negative, and diflubenzuron is not neurotoxic; but it is a moderate skin sensitizer and is synergistic with the defoliant DEF.

### General and Systemic Toxicity

***Human Toxicity.*** There have been no reported studies on the effects of diflubenzuron in humans. The reference dose set by EPA and the acceptable daily intake set by the World Health Organization are both 0.02 mg/kg/day (EPA, 1988c), based on the 1-year dog feeding study described in the next section.

*Acute and Subacute Studies in Laboratory Animals.* An acute oral study in rats determined an $LD_{50}$ for technical diflubenzuron greater than 4,640 mg/kg, the highest dose tested (EPA, 1988f). An $LD_{50}$ greater than 4,640 mg/kg is the reference level used in this risk assessment. A 28-day rat feeding study resulted in increased sulfhemoglobin values, changes in methemoglobin values, and a dose-related increase in spleen and liver weights at the lowest dose tested of 800 ppm (40 mg/kg/day) (EPA, 1988f). A study using the Dimilin® 25-percent wettable powder formulation resulted in an oral $LD_{50}$ greater than 10,000 mg/kg for the rat (EPA, 1988f).

An acute oral study in mice resulted in an $LD_{50}$ for technical diflubenzuron greater than 4,640 mg/kg, the highest dose tested (EPA, 1988f). A study using the Dimilin® 25-percent wettable powder formulation resulted in an oral $LD_{50}$ of 11,307 mg/kg for the mouse (EPA, 1988f).

A 14-day feeding study in chickens showed that 2.5 ppm (0.44 mg/kg/day, the lowest dose tested) had a depressing effect on the serum testosterone level in the developing rooster (EPA, 1988f).

In a 21-day rabbit feeding study (EPA, 1988f), 640 ppm (19.2 mg/kg/day, only dose tested) significantly increased sulfhemoglobin and methemoglobin levels. A study using the Dimilin® 25-percent wettable powder formulation resulted in an oral $LD_{50}$ greater than 4,640 mg/kg for the rabbit (EPA, 1988f).

The acute dermal $LD_{50}$ of technical diflubenzuron in rats is reported to be greater than 10,000 mg/kg (EPA, 1988f). The Dimilin® 25-percent wettable powder formulation resulted in a dermal $LD_{50}$ of greater than 20,000 mg/kg in rats (EPA, 1988f). A primary dermal irritation study classified the same formulation as slightly irritating (EPA, 1988f). Slight swelling of the cornea and a mild conjunctival reaction resulted from a primary eye irritation study in the rabbit (EPA, 1988f).

The acute inhalation $LC_{50}$ for technical diflubenzuron was greater than 2.88 mg/L in the rat, the highest dose tested, and greater than 3.75 mg/L in the rabbit, also the highest dose tested (EPA, 1988f). Two 21-day rat inhalation studies using 25 percent diflubenzuron resulted in NOELs less than the low doses tested in both cases, which were 0.5 and 0.121 mg/L/hr/day, respectively (EPA, 1988f). The first study showed increased spleen weight in male rats; and the second showed increased methemoglobin levels.

*Chronic and Subchronic Toxicity in Laboratory Animals.* A 13-week dog feeding study resulted in a systemic NOEL of 40 ppm (1 mg/kg/day) (EPA, 1988f). At the LEL of 160 ppm (4 mg/kg/day), elevated liver enzyme and methemoglobin levels were observed. The 40 ppm (1 mg/kg/day) NOEL value is used as the systemic NOEL for diflubenzuron in this risk assessment.

A 1-year feeding study in beagle dogs tested diflubenzuron doses of 0, 2, 10, 50, and 250 mg/kg/day. The percentage of methemoglobin and sulfhemoglobin increased significantly at the 10/mg/kg/day dose level, resulting in a NOEL of 2 mg/kg/day (EPA, 1988a). This is the study on which EPA's reference dose for diflubenzuron is based. A 2-year rat feeding study also resulted in a NOEL of 40 ppm (2 mg/kg/day) for methemoglobin and sulfhemoglobin effects (EPA, 1988f). A lifetime mouse feeding study resulted in a NOEL of 16 ppm (2.4 mg/kg/day) and an LEL of 80 ppm (12 mg/kg/day) (EPA, 1988f).

Methemoglobinemia occurred at the lowest dose tested of 80 ppm (12 mg/kg/day) in a 13-week mouse feeding study (EPA, 1988f). However, increased methemoglobin and sulfhemoglobin and degenerative liver cell changes were reported in another 13-week mouse feeding study at the low dose of 16 ppm (2.4 mg/kg/day) (EPA, 1988f), even though no effects were seen at that level in the mouse study previously mentioned.

A 98-day chicken feeding study showed no effect on hyaluronic acid synthesis at the highest dose tested of 250 ppm (44 mg/kg/day) (EPA, 1988f). A 13-week feeding study in sheep using 90 percent diflubenzuron resulted in methemoglobin production, decreased thyroid weights, and increased specific gravity of the urine at 500 ppm (20 mg/kg/day), the lowest dose tested (EPA, 1988f).

Several 13-week testosterone studies noted no clear treatment-related effects on testosterone levels in ducks, turkeys, pheasants, rats, or female chickens. One of the studies, however, showed higher testosterone levels in male chickens compared to controls at the end of the study (EPA, 1988f). A 6-week ChE study in sheep showed no effect at 10,000 ppm (400 mg/kg/day), the highest dose tested (EPA, 1988f).

### Reproductive/Developmental Toxicity

None of the studies reviewed showed reproductive or developmental effects at the highest doses tested, which were 8 mg/kg/day in a three-generation rat reproduction study (EPA, 1988a), 4 mg/kg/day in rat and rabbit teratology studies (EPA, 1988a), 50 ppm (7.5 mg/kg/day) in a mouse teratology study (EPA, 1988f), and 2.8 mg/kg/day in a reproduction study using bull calves (EPA, 1988f). This risk assessment uses >8 mg/kg/day as the reference level; because this is the highest dose tested, reproductive risks may be overstated.

### Carcinogenicity

EPA classifies diflubenzuron as class D, meaning that there is inadequate evidence to classify it as to human carcinogenicity. There have been four chronic feeding studies in rodents that evaluated diflubenzuron for oncogenic potential. An 80-week feeding study in mice provided suggestive evidence of a carcinogenic response in lymphoreticular tumors (EPA, 1979). A 2-year feeding study in rats

was invalidated by EPA (1988f). Subsequent chronic studies, one each in the mouse and rat, did not result in an oncogenic response (EPA, 1988f). A metabolite of diflubenzuron, p-chloroaniline, has produced study results suggestive of an oncogenic response (EPA, 1979). Although evidence suggests that diflubenzuron is not oncogenic, the conservative nature of this risk assessment necessitates the calculation of cancer risk. A cancer risk analysis was conducted using a cancer potency value of 0.01718 $(mg/kg/day)^{-1}$ (calculated by EPA, 1979), applying the conservative one-hit model to the 80-week mouse feeding study.

### Mutagenicity

***Gene Mutation.*** According to a study reviewed by EPA (1988f), technical grade diflubenzuron was not a mutagen at levels up to 1,000 µg/plate in a test using three different strains of *Salmonella typhimurium*.

***Chromosomal Effects.*** An *in vitro* cytogenetic mouse study showed no evidence of mutagenic effects at levels up to 1,500 mg/kg (EPA, 1988f). Another *in vitro* study using mouse lymphoma cells also showed no evidence of mutagenic effects at an unspecified level (EPA, 1988f). A cytogenetic analysis in the mouse (route unreported) produced a positive mutagenic effect at 500 mg/kg (NIOSH, 1987). A dominant lethal test in mice showed that diflubenzuron was not a mutagen after a single intraperitoneal administration of 1,000 or 2,000 mg/kg (EPA, 1988f).

***DNA Repair and Recombination.*** An unscheduled DNA synthesis study using human cells in culture showed no evidence of DNA damage inducing repair in activated and nonactivated systems at 1,000 µg/mL, the highest concentration tested (EPA, 1988f).

### Neurotoxicity

According to EPA (1987b), diflubenzuron is not a neurotoxin. No neurotoxicity studies are available for review.

### Immunotoxicity

In a dermal sensitization study in guinea pigs, 12 out of 20 (60 percent) exhibited a positive response, thereby classifying diflubenzuron as a moderate sensitizer (EPA, 1988f).

### Synergistic Effects

NLM (1988) reports that diflubenzuron is synergistic with the defoliant DEF; however, the defoliant is used only in the fall, while diflubenzuron is used only in the spring. Therefore, it is unlikely that the two materials would be applied together. In the NLM study (1988), toxicity

to the leafroller moth (*Platynota stultana,* doses not reported) was increased 3,319 times.

The biochemical effects of diflubenzuron (Dimilin®) were studied using *in vitro* protein and RNA biosynthesis assays with rabbit liver and muscle tissue. Dimilin® stimulated biosynthesis for both processes in liver tissue, yet inhibited both processes in muscle tissue. When fenvalerate (Pydrin®) was given with an equal dose of 2 μg/ml of Dimilin®, an antagonistic effect on RNA and protein synthesis was caused in both the liver and muscle tissues (El-Sebae et al., 1988).

### Evaluation of Data Base

According to EPA (1988c), no data gaps exist for registration studies on diflubenzuron. Sufficient information exists to quantify the risks to human health.

## Methyl Parathion

High doses of methyl parathion cause symptoms of organophosphate poisoning, which include headache, nausea, weakness, and convulsions. It has caused cleft palate and cholinesterase (ChE) inhibition in offspring when given to pregnant rats. Methyl parathion is not considered carcinogenic but it is mutagenic and genotoxic, and may cause peripheral neuropathy, based on the results of one study. It has demonstrated immunotoxic activity and may be potentiated by compounds that deplete enzymes necessary for detoxification of methyl parathion in the body.

### General and Systemic Toxicity

***Human Toxicity.*** A review of the available literature identified four studies of methyl parathion toxicity in humans. No significant effects were observed at the highest level tested of 9 mg/person/day (approximately 0.13 mg/kg/day) in a 30-day study (NLM, 1988). A 1969 study by Rider et al. (as cited in EPA, 1987c) did not produce any significant ChE inhibition in human volunteers at the highest dose tested of 19 mg/day (approximately 0.27 mg/kg/day). Subsequent studies by Rider et al. (1970 and 1971; both as cited in EPA, 1987c) used doses of 22, 24, 26, 28, and 30 mg/day in humans. Plasma and erythrocyte ChE inhibition was significant at all doses higher than 22 mg/day. Based on an average body weight of 70 kg, the NOEL from these studies is 0.31 mg/kg/day.

Symptoms of methyl parathion toxicity in humans include nausea, vomiting, abdominal cramps, diarrhea, excessive salivation, headache, giddiness, vertigo, weakness, rhinorrhea (runny nose), tightness in the chest, blurred or dimmed vision, tearing, ocular pain, loss of coordination, slurred speech, mental confusion, disorientation, drowsiness, difficulty in breathing, excessive secretion of saliva and respiratory tract mucus cyanosis, rales (abnormal sounds accompanying respiration), hypertension, convulsions, coma, and death resulting primarily from respiratory arrest (NLM, 1988).

The reference dose recommended by EPA (1988c) is 0.00025 mg/kg/day, based on the 2-year rat feeding study discussed in the next section. Other criteria include the World Health Organization's acceptable daily intake of 0.02 mg/kg/day (EPA, 1987c) and an acceptable daily intake of 0.0043 mg/kg/day calculated by the National Academy of Sciences (EPA, 1987c). Both the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend a threshold limit value of 0.0002 mg/L as a time-weighted average for inhalation exposure (EPA, 1987c).

***Acute and Subacute Toxicity in Laboratory Animals.*** Acute oral $LD_{50}$s in rats range from 3.6 (EPA, 1988g) to 24 mg/kg (EPA, 1987c). In mice, acute oral $LD_{50}$s range from 14.5 (EPA, 1987c) to 32 mg/kg (EPA, 1988g). Acute oral $LD_{50}$s reported for other species are 420 mg/kg in rabbits (NIOSH, 1987), 1,270 (NIOSH, 1987) and 41 mg/kg (EPA, 1988g) in guinea pigs, and 90 mg/kg in dogs (NIOSH, 1987). A 14-day feeding study in dogs resulted in depressed weight gain and decreased food consumption (attributed to acetylcholinesterase (AChE) inhibition) at the lowest dose tested of 2.5 mg/kg/day (EPA, 1987c).

Dermal $LD_{50}$s in rats range from 6 mg/kg (EPA, 1988g) to 120 mg/kg (EPA, 1984a). The dermal $LD_{50}$ in mice of 1,200 mg/kg was determined in a study that also showed AChE inhibition at 550 mg/kg (EPA, 1987c). The dermal $LD_{50}$ in rabbits is reported as 300 mg/kg (NIOSH, 1987). Based on another study in rabbits, EPA (1987c) has reported methyl parathion to be a weak skin and eye irritant.

Inhalation $LC_{50}$ values in rats are 0.034 (NIOSH, 1987) and 0.120 mg/L (EPA, 1988g) for a 4-hour exposure and 0.287 mg/L for a 1-hour exposure (EPA, 1984a) to methyl parathion. The inhalation $LC_{50}$ for 4 hours of exposure in mice is 0.120 mg/L (NIOSH, 1987).

EPA (1986c) has placed methyl parathion in Toxicity Category I, the most severe toxicity category. According to studies conducted by the registrant (Pennwalt Corporation, 1988), the encapsulated formulation of methyl parathion is less acutely toxic to mammals for oral, dermal, and inhalation exposures than the liquid and emulsifiable concentrate formulations. Reported values for the encapsulated formulation are as follows: oral $LD_{50}$s, 600 mg/kg for male rats and 660 mg/kg for female rats; acute dermal toxicity, greater than 2,000 mg/kg in rabbits; acute inhalation $LC_{50}$, 2,920 ppm (3,054 mg/L). However, no long-term studies using the encapsulated formulation are available, so this risk assessment uses toxicity data for technical methyl parathion.

***Chronic and Subchronic Toxicity to Laboratory Animals.*** A 2-year rat feeding study (EPA, 1988a) determined a systemic NOEL of 0.025 mg/kg/day for methyl parathion, which is the reference level used in this risk assessment. This is the same study on which EPA's reference dose is based. Erythrocyte ChE inhibition and reduced hemoglobin, hematocrit, and red blood cells were observed at the LEL

of 0.25 mg/kg/day. Two other chronic studies also were reviewed. A 2-year Wistar rat feeding study resulted in a NOEL of 2 ppm (0.1 mg/kg/day), based on ChE inhibition at the LEL of 10 ppm (0.5 mg/kg/day) (EPA, 1988a). A 1-year dog feeding study showed no adverse effects at 0.3 mg/kg/day, the highest dose tested (EPA, 1987c).

A 3-month rat feeding study determined a NOEL of 0.125 mg/kg/day; ChE inhibition, decreased hematocrit, and increased serum alkaline phosphatase and urine specific gravity were noted at the LEL (EPA, 1988a). A 3-month mouse feeding study resulted in decreased testicular weight at the lowest dose tested of 10 ppm (1.2 mg/kg/day) (EPA, 1988a). Two 3-month dog feeding studies resulted in NOELs of 0.3 mg/kg/day (EPA, 1988a) and 0.125 mg/kg/day (NLM, 1988), both based on significant ChE inhibition at the next dose level.

### Reproductive/Developmental Toxicity

The reproductive reference-level NOEL for methyl parathion is 0.25 mg/kg/day, based on decreased maternal body weight at the next dosing level of 1.25 mg/kg/day in a two-generation rat reproduction study (EPA, 1988g). A three-generation rat reproduction study resulted in a NOEL of 0.5 mg/kg/day, based on decreased weanling survival, decreased weanling weights, and an increased number of stillbirths at the next dose of 1.5 mg/kg/day (EPA, 1988g).

Two studies (EPA, 1987c) in which pregnant rats were orally dosed showed that the NOEL was less than 1.0 mg/kg/day, the lowest dose tested in both cases. One study showed decreased maternal and fetal protein synthesis, while the other resulted in significant AChE inhibition in the offspring. A teratology study in which rats were administered methyl parathion by gavage resulted in a fetotoxic NOEL of 0.3 mg/kg (EPA, 1988g). In another study, a single intraperitoneal injection in rats on day 12 of gestation resulted in a developmental NOEL of 10 mg/kg, where the next higher dose of 15 mg/kg caused mortality, retardation, and delayed ossification (EPA, 1988g). EPA (1988g) reports that a single intraperitoneal injection in mice on day 10 of gestation caused cleft palate at a dose of 60 mg/kg, resulting in a NOEL of 20 mg/kg. In a rabbit gavage study, the highest dose tested of 3 mg/kg did not cause any teratogenic, fetotoxic, or maternal effects (EPA, 1988g).

### Carcinogenicity

EPA (1987c) classifies methyl parathion as class D—that is, it is not classifiable as to carcinogenicity because of inadequate evidence of carcinogenicity in animals. The available literature includes four studies that have been conducted to determine the carcinogenic potential of methyl parathion. A 2-year rat feeding study that has been reviewed and accepted by EPA (1986c) showed no oncogenic effects. The highest dose tested was 50 ppm (2.5 mg/kg/day). The NCI conducted a 102-week mouse study and a 105-week rat study; neither demonstrated

an oncogenic response. However, EPA considers these studies supplementary because of deficiencies in experimental design and incomplete reporting of results (EPA, 1986c). A 2-year oncogenic study in rats that reported results of increased thyroid adenomas in males, increased pituitary adenomas in females, and increased Leydig cell tumors of the testes and adenocarcinomas of the uterus at a dose of 50 ppm (2.5 mg/kg/day) has been questioned by EPA (1986c) because of deficiencies in the reporting of histopathologic findings. There is insufficient information for conducting a quantitative cancer risk analysis for methyl parathion.

## Mutagenicity

Many tests have been carried out to determine the mutagenic potential of methyl parathion. Several positive results were obtained in studies that evaluated gene mutation, chromosomal aberrations, and DNA repair and recombination. Although some tests also produced negative results, EPA (1986c) has concluded that there is evidence that methyl parathion is mutagenic and genotoxic.

***Gene Mutation.*** Positive results were obtained in many studies, including Chinese hamster ovary cells with S9 activation (EPA, 1988g), in mouse lymphoma cells with activation (EPA, 1988g), in *Pseudomonas aeruginosa* (EPA, 1987c), with the Ames test using *Salmonella typhimurium* (EPA, 1987c), in *Escherichia coli* for induction of resistance to 5-methyltryptophan (EPA, 1987c), and in *Schizosaccharomyces pombe* without activation (NLM, 1988). Without activation, negative results have been reported for mutation in Chinese hamster ovary cells (EPA, 1988g), mouse lymphoma cells (EPA, 1988g), *S. typhimurium* (EPA, 1984a), *E. coli* (EPA, 1984a), *Streptmoyces coelicolor* (EPA, 1984a), *Saccharomyces cerevisiae* (EPA, 1984a), and *Schizosaccharomyces pombe* (EPA, 1984a). With activation, negative results have been reported for *S. typhimurium* (EPA, 1984a) *E. coli* (EPA, 1984a), *Saccharomyces cerevisiae* (EPA, 1984a), and *Schizosaccharomyces pombe* (EPA, 1984a).

***Chromosomal Aberrations.*** Positive results for chromosomal aberrations were observed in a cytogenetic study of exposed humans, where two out of five subjects showed significantly increased incidences of chromatid breaks and stable chromosome-type aberrations (EPA, 1984a). Methyl parathion also induced micronuclei in rat bone marrow cells (EPA, 1984a). Negative results were obtained in studies of dominant lethal effects in mice (EPA, 1988g), in human hematopoietic cells (blood-cell producing) (Hayes, 1982a), in an *in vivo* mouse study (Hayes, 1982a), in a cytogenetic assay of mouse spermatocytes (NLM, 1988), and in a recessive lethal test in *Drosophila melanogaster* (EPA, 1984a).

***DNA Repair and Recombination.*** Positive results were obtained in a recombination/conversion assay using *Saccharomyces cerevisiae*, both with and without activation (EPA, 1988g), for sister chromatid exchange in Chinese hamster U79 cells (EPA, 1987c), in Chinese hamster ovary

cells with activation (EPA, 1984a), in human lymphoid cells (EPA, 1984a), and in human lymphoma cells (EPA, 1987c). Negative results were reported for unscheduled DNA synthesis in human fibroblast cells with and without activation (EPA, 1988g), for differential toxicity in *S. typhimurium* (EPA, 1984a), and for mitotic crossover and gene conversion with and without activation (EPA, 1984a). Negative results were also reported in two other recombination/conversion assays in *Saccharomyces cerevisiae* with and without activation (EPA, 1988g, 1987c) (even though positive results were seen in the previously mentioned study with this organism) and for sister chromatid exchange in Chinese hamster ovary cells without activation (EPA, 1984a).

### Neurotoxicity

A study in chickens (NLM, 1988) testing for delayed neurotoxicity led to the conclusion that methyl parathion is not a demyelinating agent. However, the 2-year rat study discussed previously, on which the systemic NOEL is based, showed sciatic nerve damage, including loss of myelinated nerve fibers, increased myelin sheath degeneration, and Schwann cell proliferation, as well as retinal atrophy and retinal posterior subcapsular cataract (EPA, 1986c). These effects were observed in the high-dose group, but EPA has requested further information to address the possibility that these effects occurred at lower doses as well.

### Immunotoxicity

A 4-week study with rabbits (Klaassen et al., 1986) showed that oral doses of 1.5 mg/kg/day of methyl parathion led to a significant decrease in splenic germinal centers, thymus cortical atrophy, and a reduced delayed type hypersensitivity response to tuberculin following antigenic stimulation. Methyl parathion decreased the level of induced active immunity to *S. typhimurium* in Swiss mice (EPA, 1987c). Mortality resulting from *S. typhimurium* was associated with an increased number of viable bacteria in the blood, decreased total gamma-globulins and specific immunoglobulins in serum, and reduced splenic blast transformation in response to mitogens. Inhibition of immunobiological reactivity in exposed albino rats that had been vaccinated with NIICI polyvaccine was demonstrated in another study (EPA, 1987c). No skin-sensitizing was observed in methyl parathion-treated guinea pigs in a dermal sensitization study (EPA, 1987c).

### Synergistic Effects

The carbamate insecticide Temik® (aldicarb, a ChE inhibitor) was given to mice with methyl parathion at one-half the $LD_{50}$ values for each. The effect was additive, not synergistic (Dorough, 1970). Mixtures of methyl parathion and toxaphene (Attac®) were tested in bluegill sunfish in both acute and chronic studies. Acute experiments with high doses indicated an antagonistic effect. Chronic studies revealed a synergistic reaction occurring after 42 days (Auwarter, 1977).

### Evaluation of Data Base

EPA (1986c) listed the studies required for reregistration of methyl parathion. According to the summary of studies received in support of reregistration of methyl parathion (EPA, 1988g) and the reference dose tracking report (EPA, 1988c), the following have not yet been reported as received and reviewed by EPA: acute delayed neurotoxicity, 90-day neurotoxicity, special subchronic testing in rats, rodent and nonrodent chronic toxicity tests, rat and mouse oncogenicity tests, and rat and rabbit teratogenicity tests.

Although all of the studies required by EPA for reregistration of methyl parathion have not yet been submitted, sufficient information is available from EPA-reviewed studies or those available in the literature to conduct a quantitative risk assessment. The neurotoxicity evaluation is based on effects seen in a chronic rat study. The special subchronic testing in rats is required to verify these same effects; this hazard analysis relies on the original results. Chronic toxicity was analyzed using existing studies. It is not known for certain whether methyl parathion is a carcinogen. Available studies gave negative and inconclusive results. In either case, there is insufficient information to conduct a quantitative cancer risk analysis. Teratogenicity was evaluated using existing studies.

## Chlorpyrifos

Chlorpyrifos is used only in small quantities in traps in the control program. At high doses, chlorpyrifos causes symptoms of ChE inhibition, including headache, muscular twitching, nausea, and weakness. Developmental effects on the fetal skeleton were noted in one study. Chlorpyrifos has not demonstrated any oncogenic effects, but it was shown to cause direct DNA damage in bacteria and to affect DNA recombination adversely. Peripheral neuropathy was observed in a human following a large oral dose. Chlorpyrifos is not a skin sensitizer.

### General and Systemic Toxicity

***Human Toxicity.*** A 20-day human ChE inhibition study established the systemic NOEL of 0.03 mg/kg/day used as the reference level in this risk assessment (EPA, 1988a). EPA's reference dose is also based on this study. After 90 days of treatment, one person in the high-dose (0.1 mg/kg/day) group exhibited blurred vision and nasal discharge. The mean plasma ChE level in the high-dose group was 65 percent lower than the control group after 9 days of treatment. A study of the dermal toxicity of chlorpyrifos to humans demonstrated that four 12-hour dermal doses of 25 mg/kg depressed plasma ChE levels (NLM, 1988).

Symptoms of chlorpyrifos toxicity include headache, dizziness, extreme weakness, ataxia, pinpoint pupils, twitching, tremors, nausea, slow heartbeat, pulmonary edema, and sweating (EPA, undated). Higher doses may result in disorientation, difficult breathing, convulsions,

coma, and death, primarily resulting from respiratory arrest (NLM, 1988).

The reference dose recommended by EPA (1988c) is 0.003 mg/kg/day, based on the 20-day human study and a safety factor of 10. The World Health Organization set an acceptable daily intake for chlorpyrifos of 0.01 mg/kg/day (EPA, 1988c). The American Conference of Governmental and Industrial Hygienists has set a threshold limit value of 0.0002 mg/L as a time-weighted average for inhalation exposure (NIOSH, 1987).

*Acute and Subacute Toxicity to Laboratory Animals.* Reported acute oral $LD_{50}$s in rats range from 82 (NIOSH, 1987) to 245 mg/kg (Hayes, 1982a). The acute oral $LD_{50}$ in mice has been reported as 60 (NIOSH, 1987) and 152 mg/kg (Hayes, 1982a). NIOSH (1987) reports $LD_{50}$s for other mammalian species as 504 mg/kg in guinea pigs and 1,000 mg/kg in rabbits. The reference level used in this analysis is 82 mg/kg.

Dermal $LD_{50}$s are 202 and 2,000 mg/kg in rats and rabbits, respectively (NIOSH, 1987).

A 2-week inhalation study in rats showed a depression in plasma and erythrocyte ChE following 10 6-hour exposures to 0.00001 mg/L chlorpyrifos over 14 days (EPA, 1988h).

*Chronic and Subchronic Toxicity to Laboratory Animals.* A 2-year chlorpyrifos feeding study in dogs resulted in a NOEL of 0.03 mg/kg/day (EPA, 1988h). At the LEL of 0.1 mg/kg/day, plasma ChE inhibition was noted; at higher doses, erythrocyte and brain ChE was inhibited and liver weights increased.

A 2-year rat feeding study resulted in a NOEL of 0.1 mg/kg/day, based on ChE inhibition at the LEL of 1 mg/kg/day (EPA, 1988h). A 3-month dog feeding study determined a NOEL of 0.01 mg/kg/day, with plasma ChE inhibition observed at 0.03 mg/kg/day (EPA, 1988h). A 6-month rat feeding study resulted in a NOEL of 0.15 mg/kg/day (EPA, 1988h). In a 6-month feeding study in rhesus monkeys, the NOEL was 0.08 mg/kg/day (EPA, 1988h), also based on ChE inhibition. Other subchronic feeding studies failed to determine a NOEL because of ChE inhibition at the lowest doses tested of 0.5, 0.8, and 1.0 mg/kg/day in rats, dogs, and rats, respectively (EPA, 1988h).

A 3-month inhalation study in rats using nose-only exposure showed no effects at the highest dose tested of 20.6 ppb (0.000287 mg/L) (EPA, 1988h).

## Reproductive/Developmental Toxicity

A two-generation rat reproduction study resulted in decreased weight gain at a dose level of 1.2 mg/kg/day, giving a NOEL of

0.8 mg/kg/day (EPA, 1988h), which is the reproductive/developmental NOEL used in this risk assessment. No teratogenic or fetotoxic effects were noted in this study. A three-generation rat reproduction study showed no reproductive effects at the highest dose tested of 1.0 mg/kg/day (EPA, 1988h). A rat teratology study showed no teratogenic or fetotoxic effects at the highest dose tested of 15 mg/kg/day (EPA, 1988h). A teratology study in mice resulted in a fetotoxic NOEL of 10 mg/kg/day, based on decreased fetal length and increased skeletal variants at the LEL of 25 mg/kg/day (EPA, 1988h).

### Carcinogenicity

Two oncogenicity studies have been submitted, and neither suggested that chlorpyrifos was a potential oncogen (EPA, undated). Doses up to 3.0 mg/kg/day in rats and 2.25 mg/kg/day in mice failed to produce any oncogenic effects (EPA, 1988i). However, the rat study was graded only as supplementary upon EPA review because there was an insufficient number of animals and tissues at final sacrifice for a valid assessment. EPA is requiring that the rat study be repeated.

### Mutagenicity

***Gene Mutation.*** Chlorpyrifos was negative for gene mutation in *Escherichia coli* and Chinese hamster ovary cells, both with and without activation in each case (EPA, 1985).

***DNA Repair and Recombination.*** A test for unscheduled DNA synthesis in fibroblasts of an unspecified species was negative, both with and without activation (EPA, 1985). Chlorpyrifos gave positive results for direct damage in *Bacillus subtilis* and *E. coli* (EPA, 1985). The presence of activation was not specified in the study. Chlorpyrifos was weakly positive in a mitotic recombination test in *Saccharomyces cerevisiae*, with or without metabolic activation (EPA, 1985).

### Neurotoxicity

An acute delayed neurotoxicity test in hens was negative at doses of 50 and 100 mg/kg (EPA, 1988h). A 42-year-old man ingested 300 mg/kg of chlorpyrifos in a suicide attempt. Six weeks after ingestion, clinical examination and a nerve biopsy indicated peripheral axonal neuropathy (Lotti et al., 1986).

### Immunotoxicity

According to a study in the guinea pig reviewed by EPA (1985), chlorpyrifos showed no evidence of causing dermal sensitization.

### Synergistic Effects

No information was available on synergistic effects from combinations of chlorpyrifos and other chemicals.

### Evaluation of Data Base

Of the toxicology studies required for reregistration of chlorpyrifos by EPA (1984b), a chronic toxicity test in a rodent and a rat oncogenicity study have not yet been reported as received and reviewed by EPA.

Although all of the studies required by EPA for reregistration of chlorpyrifos have not yet been submitted, sufficient information is available from EPA-reviewed studies and studies in the literature to conduct a quantitative risk assessment. Chronic toxicity was evaluated using existing studies. Although further oncogenicity testing is required, none of the studies submitted to date indicates that chlorpyrifos has any oncogenic potential. No cancer risk analysis was conducted.

## Propoxur

Propoxur is used only in small amounts in traps in the control program. High doses of propoxur may cause symptoms of ChE inhibition, including blurred vision, sweating, nausea, and pallor. No developmental effects were observed in laboratory studies with propoxur, although low birth weights were reported in one case. Propoxur is a probable human carcinogen; and positive mutagenicity results have been reported for gene mutation, chromosomal aberrations, and unscheduled DNA synthesis. Propoxur, which may cause neuropathy, is not a skin sensitizer and is potentiated by casein.

### General and Systemic Effects

***Human Toxicity.*** In a study reviewed by EPA (1987c), a single dose in human volunteers of 0.36 mg/kg (only dose tested) caused short-term stomach discomfort, blurred vision, moderate facial redness, and sweating. Erythrocyte ChE was temporarily inhibited (43 percent). Because there are no studies that determined a lower NOEL, 0.36 mg/kg/day is the reference level used for evaluation of systemic toxicity in this risk assessment. The study mentioned previously is the one on which EPA's reference dose (0.004 mg/kg/day) is based. In another study (EPA, 1987c), ingestion of 1.5 mg/kg resulted in symptoms of ChE depression. In a third short-term study (EPA, 1987c), oral doses of 0.15 or 0.20 mg/kg were given at five 30-minute intervals, for total doses of 0.75 and 1.0 mg/kg. In all subjects, erythrocyte ChE was significantly inhibited. The authors noted that a propoxur dose was better tolerated if it was divided into portions and given over time, as opposed to a single dose.

Symptoms of propoxur toxicity include nausea, vomiting, sweating, weakness, rapid heartbeat, blurred vision, and pallor.

EPA's reference dose for propoxur is 0.004 mg/kg/day; the acceptable daily intake recommended by the World Health Organization is 0.02 mg/kg/day (EPA, 1988c). The American Conference of Governmental Industrial Hygienists recommends a threshold limit value of

0.0005 mg/L as a time-weighted average for inhalation exposure (NIOSH, 1987).

***Acute and Subacute Toxicity to Laboratory Animals.*** Reported acute oral $LD_{50}$s in rats range from 70 (NIOSH, 1987) to 150 mg/kg (EPA, 1988i). This risk assessment uses the reference level of 70 mg/kg. Acute oral $LD_{50}$s in mice range from 23.5 (NIOSH, 1987) to 39 mg/kg (Hayes, 1982a). Inhibition of plasma and erythrocyte ChE was observed at 10 mg/kg (lowest dose tested) in an acute oral study in rats (EPA, 1988i). Another acute oral rat study showed that brain ChE was also inhibited at 10 mg/kg, the lowest dose tested (EPA, 1988i). A 28-day rat feeding study resulted in a NOEL of 3 mg/kg/day, based on ChE inhibition at the LEL of 10 mg/kg/day (EPA, 1987c).

The acute dermal $LC_{50}$ of propoxur was reported to be greater than 2,400 mg/kg (EPA, 1987c). A primary dermal irritation study in rabbits did not result in any irritation at 500 mg/kg on abraded skin (EPA, 1988i). A primary eye irritation study in rabbits showed no ocular irritation at 100 mg propoxur (EPA, 1988i).

The acute inhalation $LC_{50}$ in rats is 0.832 mg/L for 4 hours of exposure (EPA, 1988i). A 6-hour inhalation study in rats resulted in a NOEL of 0.030 mg/L, with measurable plasma and erythrocyte ChE inhibition at the LEL of 0.078 mg/L (EPA, 1988i).

***Chronic and Subchronic Toxicity to Laboratory Animals.*** In a 12-month dog feeding study, a NOEL of 5 mg/kg/day was established, based on increased mean liver weight and N-demethylase activity and increased plasma cholesterol at the LEL of 15 mg/kg/day (EPA, 1988a). A 2-year dog feeding study resulted in a NOEL of 6.25 mg/kg/day, based on increased liver weight and decreased body weight at the LEL of 18.7 mg/kg/day (EPA, 1987c). Another 2-year dog feeding study resulted in a NOEL of 18.75 mg/kg/day (EPA, 1988i). A 106-week rat feeding study resulted in a NOEL of 10 mg/kg/day, based on depressed weight gain at 50 mg/kg/day (EPA, 1987c). Increased liver weights were observed in a 2-year rat feeding study, where the NOEL was 12.5 mg/kg/day (EPA, 1987c). A 2-year mouse feeding study caused depressed weight gain. The NOEL was 105 mg/kg/day (EPA, 1988a).

Subchronic studies include a 13-week rhesus monkey feeding study, where decreased plasma ChE was noted at 40 mg/kg/day (only dose tested; EPA, 1988i). A 16-week rat feeding study produced no effects at 40 mg/kg/day, the highest dose tested (EPA, 1987c). Decreased body weight gain and food consumption were noted in a 2-month rat feeding study that resulted in a NOEL of 100 mg/kg/day (EPA, 1988i).

A 3-month inhalation study in rats resulted in a NOEL of 0.0187 mg/L; in the same study, exposure to 0.0317 mg/L for 5 days per week for 12 weeks caused plasma, erythrocyte, and brain ChE depression (EPA, 1988i).

### Reproductive/Developmental Toxicity

A three-generation rat reproduction study (EPA, 1988i) determined a reproductive/developmental NOEL of 12.5 mg/kg/day, which is used as the reference level in this risk assessment. The NOEL was based on decreased pup number at the next highest dose of 37.5 mg/kg/day (EPA, 1988i). In a rat teratology study, the average weight of the fetuses was significantly lower at doses of 150 mg/kg/day. Decreased maternal body-weight gain and food consumption were noted at 150 mg/kg/day, but no teratogenic effects were seen at 500 mg/kg/day, the highest dose tested (EPA, 1988i). No maternal toxic, fetotoxic, or teratogenic effects were seen in a rabbit teratology study at 10 mg/kg/day, the highest dose tested (EPA, 1988i).

### Carcinogenicity

The Toxicology Branch of the Hazard Evaluation Division of EPA considers propoxur to be a probable human carcinogen (class B). A 2-year rat oncogenicity study resulted in bladder papillomas in a male at a dose of 50 mg/kg/day, the mid-dose level. At the high dose of 250 mg/kg/day, carcinoma of the bladder was observed in some males and females, and the females also had an increased incidence of carcinoma of the uterus (EPA, 1987c). The cancer potency value calculated for propoxur based on this study is 0.00079 $(mg/kg/day)^{-1}$ (EPA, 1988i). A 2-year feeding study in mice revealed no evidence of increased tumor frequency at 900 mg/kg/day, the highest dose tested (EPA, 1987c).

### Mutagenicity

***Gene Mutation.*** The Ames test (without activation) was negative for *S. typhimurium* and *E. coli* (EPA, 1988i). However, according to NIOSH (1987), positive results for gene mutation were obtained in studies using *S. typhimurium* and *Saccharomyces cerevisiae* without activation.

***Chromosomal Aberrations.*** Several studies reviewed by EPA were negative for chromosomal aberrations (1988i), including a dominant lethal test in mice; a micronucleus test in mice; a test for point mutation, mitotic crossing-over, or mitotic gene conversion in the yeast *S. cerevisiae*; and a test for spermatogonial aberrations in Chinese hamsters. However, NIOSH (1987) reported positive results in a cytogenetic analysis in hamsters and a dominant lethal test in mice.

***DNA Repair and Recombination.*** A test for unscheduled DNA synthesis in rats was positive (EPA, 1988i); however, a recombination and reversion assay in *Bacillus subtilis*, a test for DNA damage and repair in rat spleen cells, and a test for sister chromatid exchange in human lymphocytes without S9 activation were all negative (EPA, 1988i).

### Neurotoxicity

No neurotoxic effects were observed at the highest doses tested (doses up to 1,000 mg/kg) in three chicken studies (EPA, 1988i). However, in a 2-year feeding study in rats, an increased incidence of unspecified neuropathy was noted at 250 mg/kg/day (EPA, 1988i).

### Immunotoxicity

Available information (EPA, 1987c, 1988i) indicates that propoxur is not a dermal sensitizer. No other information is available on potential immunotoxic effects.

### Synergistic Effects

According to Hayes (1982a), the acute oral toxicity of propoxur increased when rats were fed diets containing casein, a dairy protein. In an EPA-reviewed study (1988i), propoxur was not potentiated by the organophosphate dichlorvos.

### Evaluation of Data Base

According to EPA (1988c), data gaps for propoxur are a short-term dog feeding study to determine a NOEL for ChE effects and verification of body-weight decrease in a 2-year rat study.

Because no NOEL was determined for ChE effects in the study used to set the systemic toxicity reference value (as discussed in the preceding section on human toxicity), an extra uncertainty factor of 10 is incorporated into the risk analysis for systemic effects for propoxur, following the example EPA set in determining its human reference dose. Chronic effects were evaluated using existing studies.

## Inert Ingredients: Xylene

### General and Systemic Toxicity

No studies were available that evaluated the effects of xylene on humans under controlled conditions. Symptoms attributed to xylene toxicity include a burning sensation in the mouth or stomach and vomiting of blood following ingestion; reddened skin and blisters following skin contact; and headache, vertigo, and incoordination following inhalation (NLM, 1987). According to Klaassen et al. (1986), xylene may produce pulmonary edema following acute inhalation exposure, and has been reported to affect male reproductive capacity.

EPA's reference dose for xylene is 2 mg/kg/day (EPA, 1988a). The American Council of Governmental Industrial Hygienists recommends a threshold limit value for inhalation exposure of 100 ppm as a time-weighted average (NIOSH, 1987).

The reported acute oral $LD_{50}$ value in rats is 4,300 mg/kg (NLM, 1987), which is the reference level used in this assessment, and 1,590 mg/kg

in mice (Klaassen et al., 1986). Moderate skin irritation resulted from a dermal dose to rabbits of 500 mg (15 mg/kg/day) (NLM, 1987). The inhalation $LC_{50}$ is 29 mg/L for rats (Klaassen et al., 1986).

A 2-year oral rat study established a systemic NOEL of 179 mg/kg/day, which is the reference level used in this assessment; the NOEL was based on observations of hyperactivity, decreased body-weight gain, and increased mortality (EPA, 1988a).

### Reproductive and Developmental Toxicity

A teratology study in mice reported an increased incidence of resorptions and maternal toxicity at the high-dose level of 1 mg/kg/day of *m*-xylene, the predominant isomer in xylene. Doses of 0.75 mg/kg/day of either *o*- or *p*-xylene caused these same effects, in addition to an increased incidence of cleft palate. The reproductive reference-level NOEL for xylene is 0.3 mg/kg/day (NLM, 1988).

### Carcinogenicity

No data on the carcinogenicity of xylene were available. However, Von Burg (1982) stated that the latest evidence indicates that xylene isomers are not carcinogenic.

### Mutagenicity

Xylene was negative for mutagenicity in the Ames test using *S. typhimurium* with and without activation and was negative for chromosomal effects in the mouse micronucleus assay (NLM, 1988).

### Immunotoxicity

No information was available on the immunotoxicity of xylene.

### Neurotoxicity

A study in gerbils indicated that xylene is neurotoxic (Rosengren et al., 1986). Increased concentrations of the astroglial proteins S-100 and GFA were found in the frontal cerebral cortex of the brain. Increased DNA, attributed to a proliferation of cells, was found in the posterior cerebellar vermis. A study in humans (Savolainen et al., 1980) showed that inhalation exposure to *m*-xylene at 90 ppm adversely affected reaction time, manual coordination, body balance, and electroencephalogram patterns.

### Synergistic Effects

NLM (1987) reported two studies in laboratory animals indicating that xylene is synergistic with some compounds. Rats exposed to xylene and *n*-hexane showed an increase in blood serum concentration of the neurotoxic metabolite 2,5-hexanedione. Another study reported that

ingestion of ethyl alcohol potentiated the adverse behavioral effects of xylene (dose levels not specified) in animals and caused liver damage when combined with doses of xylene that caused no damage when given alone.

# Section B3

# Human Health Exposure Analysis

## Introduction

This section discusses in detail the information, assumptions, and calculations used to estimate the extent of human exposure to insecticides used to control the boll weevil. Exposure during eradication and suppression programs is considered. This section also contains basic information about the methods used to analyze exposure, including an explanation of terms. This section presents the assumptions and calculations used to estimate the level of exposure to insecticides under different circumstances and the effects on humans.

For humans to be exposed to an insecticide, the insecticide must be present in their immediate environment, such as in the air they breathe, on their skin, or in their food or water. The amount of insecticide present in a person's immediate environment is called the exposure level. Also, an insecticide must get into the body somehow. If an insecticide is in the air, it may be inhaled; if it is on the clothing or skin, it may penetrate the skin. If an insecticide is on food or in water, it may be consumed. The amount of insecticide that moves into the body by any of these routes is called the dose.

Although two people may be exposed to the same amount of insecticide, one may receive a much lower dose than the other by wearing protective clothing, using a respirator, or washing immediately after being sprayed. ***Exposure***, then, is the amount of insecticide in the immediate environment that can be taken into the body; ***dose*** is the amount of the insecticide that actually enters the body.

To analyze the level to which a person has been exposed, conservative estimates (that is, estimates that will provide the greatest margin for safety) and simplified circumstances are used. By calculating a more conservative dose than a typical case, there is a better chance that the risks are not underestimated. Simplified circumstances that can be readily understood and related to existing studies or hypothetical situations are also used. For example, a typical person might eat three full meals a day consisting of various foods. For the purpose of the analysis, a simplified diet consisting of a single food item that has been measured for the amount of chemicals it contains would be studied. A conservative diet assumes that a person eats 0.5 kilogram (kg) (1.1 pounds) of this food item per day. This amount is more than a person might actually eat of that single food item in a day, which results in a conservative prediction of a person's reaction. Limiting the diet of a study subject to a single food item simplifies the analysis.

The risk to humans is calculated by comparing the amount of a chemical that they might take into their bodies (dose) to the amount of the same chemical that toxicologists believe may cause harm (hazard). For example, toxicologists may conservatively predict that hot dogs can

cause a harmful reaction in the body if more than 20 per day are eaten. By analyzing the level of exposure (the amount of a chemical that *could* be taken in), it might be predicted that the average person typically would eat 3 hot dogs a day, and in an extreme case, the same person might eat 10 hot dogs a day. By comparing the amount of hot dogs eaten to the amount that is expected to cause harm, it might then be concluded that the average person would suffer no ill effects from eating hot dogs, even in an extreme situation (10 a day).

Analyzing exposure levels also includes more than one scenario to cover various possibilities. In the hot dog example, a typical exposure (3 hot dogs) and an extreme exposure (10 hot dogs) were considered.

In analyzing exposure levels for insecticides that might be used in the National Boll Weevil Cooperative Control Program, three different scenarios are considered. These three scenarios represent how much a person might be exposed to insecticides during the program. The first scenario—the typical case—assumes that exposure to the insecticide results from routine operations and that no accidents occur. It is also assumed in typical scenarios that the workers do *not* follow the safety measures on the label, such as using respirators or special protective clothing. This assumption is used to show the degree of risk that could exist if label directions are not followed.

Under the second scenario, exposures from extreme situations are considered. In these extreme situations, the dose is greater, or the number of exposures is greater than for typical situations. As in the typical scenario, common safety practices, such as wearing protective clothing and washing frequently to remove insecticides from the skin, are considered to be ignored.

The third scenario considers accidental situations. An example is a worker spilling an insecticide on himself while loading application equipment.

## Factors Affecting Human Exposure

### Characteristics of the Pesticide Application Program

#### Application Methods

Most of the insecticides proposed for the National Boll Weevil Cooperative Control Program would be applied by fixed-wing aircraft or helicopter. Cotton fields that cannot be sprayed by aircraft may be treated using ground application equipment, such as mist blowers and tractor-mounted sprayers (hiboys). Ground equipment applicators would also be used to dress the edges of fields that were avoided for safety reasons during aerial applications. Other chemicals will be used in boll weevil traps; exposures to these chemicals are not calculated because they are not used on crops and are generally inaccessible to humans.

For aerial applications, only aircraft capable of maneuvering and operating at slow airspeeds close to the cotton canopy would be used. For example, a Cessna 188 AgTruck aircraft could be used to apply insecticides to cotton crops. At slower airspeeds, pilots can more easily identify hazards and treatment boundaries and can quickly stop spraying the insecticide if necessary. In addition, flying low over treatment areas minimizes the amount of insecticide that drifts both within and away from target areas.

In the National Boll Weevil Cooperative Control Program, average airspeed is expected to be 90 to 110 mph, and the aircraft will spray the insecticides from a height of 3 feet to a maximum of 10 feet above the canopy. Flat fan nozzles, such as the 8002, will be used to spray the insecticide. The median size (by volume) of the droplets sprayed will range from 150 to 200 microns in diameter, depending on operational conditions. The anticipated maximum payload per aircraft will be 80 gallons.

Program supervisors may choose to use alternative insecticide application methods, especially in areas where aerial application is impractical or hazardous. In situations where aircraft cannot be used, ground application equipment, such as mist blowers or hiboys, will be used. Tractor-mounted ground sprayers (hiboys) can be driven through the fields to apply the insecticide very near the canopy. Mist blowers dispense a fine directed mist from a truck-mounted blower as the operator drives along the field borders.

To minimize drift and runoff, the insecticides will be applied only when weather conditions favor effective insecticide penetration and dispersal into target areas. Under less than favorable conditions, the spray drift is more likely to move into nontarget areas, which increases the amount of insecticide humans and wildlife are exposed to through drift and insecticide runoff. Operations will be suspended when any of the following five conditions exist in the treatment area (if the directions on the insecticide label are more restrictive than the conditions listed below, the label will be followed):

- Wind velocity is greater than 10 mph, unless a more restrictive wind speed is mandated by State law.
- Precipitation is present or imminent.
- Fog or other weather conditions limit visibility.
- Air turbulence is so great that it affects normal application.
- Low-elevation temperature inversion is evident.

Before any aircraft begins to apply an insecticide, it is calibrated and characterized. Calibration is the adjustment of the spray system so that the proper amount of insecticide is applied per unit area.

Characterization is the evaluation of spray droplet size and the determination of effective spray swath width. (A spray swath is the area on which the aircraft deposits the insecticide with each pass.) Treatments are only applied to fields that have exceeded a treatment threshold. Program personnel observe the applications and maintain radio contract with the pilot.

## Insecticide Characteristics

Most insecticides are packaged and sold by the manufacturer as a concentrate, either in liquid or powder form, with a specified amount of active ingredient per unit volume or mass of the concentrate. Inert ingredients form the remaining portion of the concentrate. Characteristics of the chemicals being considered for use in control programs are provided in table B3-1.

Before the chemical is applied, the insecticide may be mixed with a carrier according to the manufacturer's label instructions for the particular treatment purpose and the desired application rate in pounds of active ingredient per acre. (Carriers may include water for methyl parathion, malathion RTU, and azinphos-methyl, and vegetable oil or vegetable oil and water for diflubenzuron. The ULV malathion formulations being considered for use in the program are not mixed with a carrier and are applied as received from the manufacturer in liquid form.) Insecticide concentrate is prepared for application and then transferred to application equipment by a person called a mixer/loader. The insecticides typically are stored in large tanks or in the 30- to 55-gallon drums in which they are shipped from the manufacturers and distributors.

## Worker Categories

Several types of people are involved in the application of pesticides to crops. In this analysis, groups of workers that are representative of a typical boll weevil insecticide application crew have been chosen for the assessment. Table B3-2 lists the worker categories and the estimated number of hours and days they were assumed to be exposed; extreme exposure times are also considered. The functions of some of these groups are briefly described below.

In some spraying operations, flaggers may be stationed at each end of the field being treated. Flaggers sit in trucks on which are mounted flags or beacons to guide the pilot in making the next spray swath. After each swath is completed, the flagger moves the appropriate distance so that the pilot can direct the next swath to be sprayed. For instance, if the swath width is 75 feet, the flaggers would align the center of the first swath at about 37.5 feet from the edge of the field being treated (assuming no wind) and then move 75 feet toward the other side of the field for each succeeding swath until treatment is completed.

**Table B3-1. Insecticide Characteristics**

| Insecticide | Trade name | Formulation and lb a.i./gal | Active ingredient |
|---|---|---|---|
| Malathion | Cythion ULV<br>Cythion RTU<br>Fyfanon ULV | Liquid, 9.33<br>Liquid, 4.1<br>Liquid, 9.79 | 0,0,-dimethyl phosphorodithioate of diethyl mercaptosuccinate |
| Azinphos-methyl | Guthion 2S/2L | Liquid, 2 | Phosphorodithioic acid, 0,0-dimethyl -S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)methyl] ester |
| | Lanco Azinphos-methyl 2EC | Liquid, 2 | |
| | Clean Crop® Azinphos-methyl 2 | Liquid, 2 | |
| Diflubenzuron | Dimilin 25W | Wettable powder, 2 | N-[[(4-chlorophenyl) amino]carbonyl]-2,6-difluorobenzamide |
| | Dimilin 2F | Liquid, 2 | |
| Methyl parathion | Penncap M® | Microencapsulated, 2 | Phosphorothioic acid, 0,0-dimethyl-0-(4-nitrophenyl) ester |

**Table B3-2. Types of Pesticide Application Workers and Exposure Times**

| Workers categories[a] | Exposure times (hours exposed per day) | | Exposure times (days exposed per year) | |
|---|---|---|---|---|
| | Typical[b] | Extreme | Typical | Extreme |
| Pilot (99) | 8 | 12 | 248 | 240 |
| Mixer/Loader (100) | 8 | 12 | 208 | 240 |
| Flagger (100) | 8 | 12 | 208 | 240 |
| Observer (100) | 8 | 12 | 208 | 240 |
| Environmental monitoring crew (100) | 8 | 12 | 208 | 240 |
| Ground Applicators: | | | | |
| Hiboy Operators (1) Mist Blower (99) | 8 | 12 | 208 | 240 |

[a] The numbers in parentheses refer to the percentage of acreage on which the particular type of worker is expected to work. Pilots and mist blowers, for example, are considered to work together on 99 percent of the acres in this program, while hiboy operators are expected to cover the remaining 1 percent of the acres.

[b] Eight hours was a conservative estimate of the length of the workday. Workers are probably exposed for a shorter period each day.

Ground observers are program personnel who perform a quality assurance/quality control function. These workers observe program operations to ensure that insecticide applications are made on the proper fields, that spraying operations are carried out properly, and that spray drift from aerial application is controlled. (Dye cards may be used to determine the extent of the spray drift.)

After the field has been sprayed, an environmental monitoring team may evaluate the area to determine the effectiveness of the treatment. Generally, the crews will not enter the sprayed fields but will evaluate the field borders. If they do enter the field, they will wait the length of time specified on the insecticide label. This time allows the insecticide to degrade to safe concentrations so the workers are exposed to as little insecticide as possible. The environmental monitoring team also collects samples of soil, water, leaves, or garden vegetables on a routine or emergency basis. The purpose of this activity is to determine if drift has occurred, the amount of drift, and whether it poses a substantial risk to the public.

## Accidental Exposures

Although accidents are unlikely if operations are performed in a safe, prescribed manner, the potential for accidents nevertheless exists before and during insecticide applications. Before the application, the insecticide concentrate could spill or a hose could rupture, which would spray

nearby workers. During aerial applications, accidents may occur because of mechanical failure of the aircraft, pilot error, or environmental conditions. Mechanical failure, which may result in loss of power or maneuverability, could result in a crash landing. Mechanical failure also could be in the form of a malfunctioning insecticide-release mechanism, which could unintentionally spray nontarget areas or release the payload. Pilot error may result in unintentional spraying in nontarget areas. Finally, unforeseen environmental conditions may occur, such as strong gusts of wind, which could cause insecticide to be sprayed in nontarget areas or cause the aircraft to crash.

## Potential Routes of Human Exposure

The routes of exposure considered in estimating doses to workers and the public from routine operations and accidents are listed in tables B3-3 and B3-4 and are described below.

### Exposures From Routine Operations

The highest doses during routine insecticide applications are to workers who may be exposed while (1) mixing and loading insecticide into application equipment; (2) applying insecticide using ground equipment or aircraft; and (3) supervising or monitoring aerial applications. The most significant source of exposure to persons who do not handle the insecticide containers or spray equipment in routine operations is from insecticide that drifts away from the targeted areas.

During routine operations, workers may get insecticide concentrate, mixture, or drifted spray droplets on their skin or rub against recently sprayed vegetation. They may inhale insecticide if they do not wear protective devices in the sprayed area.

Members of the general public who are within the area of drift of the spray droplets may also get insecticide on their skin or inhale insecticide but their exposure is likely to be relatively low compared to the exposure of workers directly involved in the spraying operations. The public may also ingest insecticide from food containing insecticide residues. Food items, such as garden vegetables (legumes), wild berries, or game animals (deer), may have received some level of insecticide from spray drift or, in the case of animals, may have fed on plants with insecticide residues from the spray area. Exposure also could result from drinking water or eating fish from a lake or stream exposed to insecticide drift.

### Exposures From Accidents

If an accident occurs, workers and members of the public may be exposed to much greater amounts of insecticide than they would under normal circumstances. Workers who spill the concentrate or some of the prepared spray mixture on their skin during mixing, loading, or spraying operations or who are doused when a transfer hose breaks would be dermally exposed. Workers or members of the public who are accidentally sprayed with insecticide because they are beneath a

**Table B3-3. Routes of Exposure for Workers and Members of the Public for Routine Scenarios**

**Workers**

**Workers and potential routes of exposure:**

- Pilot—Inhalation and dermal
- Mixer/loader—Inhalation and dermal
- Observer—Inhalation and dermal
- Ground applicators—Inhalation and dermal
- Monitoring team—Inhalation and dermal

**Typical exposure assumptions:**

- Typical exposure is experienced by pilots, mixer/loaders, and ground applicators
- Observers receive drift at 100 feet
- Label safety precautions are not necesarily followed with respect to protective clothing
- Workday is 8 hours
- Label reentry waiting period is followed by monitoring team
- Monitoring team enters area receiving direct spray

**Extreme exposure assumptions:**

- Protective clothing is not worn and safety precautions are totally ignored
- Upper 95-percent confidence level for exposure level assumed for pilots, mixer/loaders, and groundapplication crews
- Observers receive drift at 25 feet
- Workday is 12 hours
- Monitoring team enters area receiving direct spray 1 hour after application

**Public**

**Nearby residents:**

- Dermal and inhalation from drift
- Dietary from consumption of water, fish, venison, legumes, and berries

**Typical exposure assumptions:**

- Drift and inhalation occur at a distance of 500 feet
- Oral doses of drift from a distance of 100 feet

**Extreme exposure assumptions:**

- Drift and inhalation occur at a distance of 100 feet
- Oral doses of drift from a distance of 25 feet

**Table B3-4. Exposure Scenarios for Accidents**

- Insecticide concentrate is spilled onto a worker.
- A broken hose spills insecticide mixture onto a worker.
- Persons enter a freshly sprayed field.
- An adult is directly sprayed.
- Food items—berries and legumes—are directly sprayed.
- Drinking water is consumed from reservoir into which 80 gallons of pesticide are released.

spray aircraft would receive a dermal and an inhalation dose. The dermal dose would depend on the concentration of insecticide in the spray mix, how much exposed skin was sprayed, the extent to which the person's clothing absorbed insecticide (some clothing is water repellent or may preferentially absorb insecticides, but other material would permit penetration of the insecticide to the skin), and the time that elapses before the person can wash. Indirect dermal (reentry) exposure may occur if workers or members of the public brush against wet vegetation in the sprayed area.

Members of the public may be accidentally exposed to the insecticide by eating food or drinking water that has been directly sprayed. For example, members of the public may eat berries or legumes that have been directly sprayed. Exposure to even higher levels of insecticide is possible if a container of insecticide concentrate were to break and spill into a drinking water supply (reservoir). Table B3-4 presents a list of the accident scenarios considered in this exposure analysis.

## Calculations of Human Exposures

Calculations of human exposures to chemicals require consideration of a variety of factors. Exposure is a function of the dose to which a person is exposed, the length of time a person is exposed, the route of exposure, and occasionally other contributing factors.

It is possible to make reasonable estimates of certain factors, such as the length of exposure each workday (which is assumed to be 8 hours in this exposure analysis), considered in the exposure calculation. In other instances, it is necessary to consult scientific literature to make reasonable estimates of the quantity of insecticide to which a person may be exposed. For example, the best way to estimate the exposure that pilots receive from insecticide applications is to actually measure the amount of insecticide found in their bodies by analyzing urine samples. Based on data from past exposures under controlled situations, it is then possible to make reasonable predictions of future exposures to various pesticides.

Results of the environmental transport and fate modeling (section B8 of this appendix) give estimates of insecticide concentrations in environmental components (such as air, water, and vegetation) that may lead to human exposure. The calculated exposures represent a full range of the types and magnitude of exposure that could occur, while restricting the calculations to a reasonable number of cases. To avoid underestimating exposures, many parameters and assumptions were chosen so that calculated exposures would not be underestimated.

As previously described, some of the exposures are described as routine, meaning that they could occur under routine circumstances. Routine exposures were further divided into typical and extreme exposures.

Observer and flagger routine exposures throughout the analysis were based on typical application rates and spray drift at 100 feet from the boundary of a treated area, while pilots and mixer/loaders were assumed to receive an average dose as defined by toxicological studies. Extreme exposures to observers and flaggers were based on drift at 25 feet offsite, and pilots and mixer/loaders were assumed to receive a dose at the upper limit of the 95-percent confidence interval (described below).

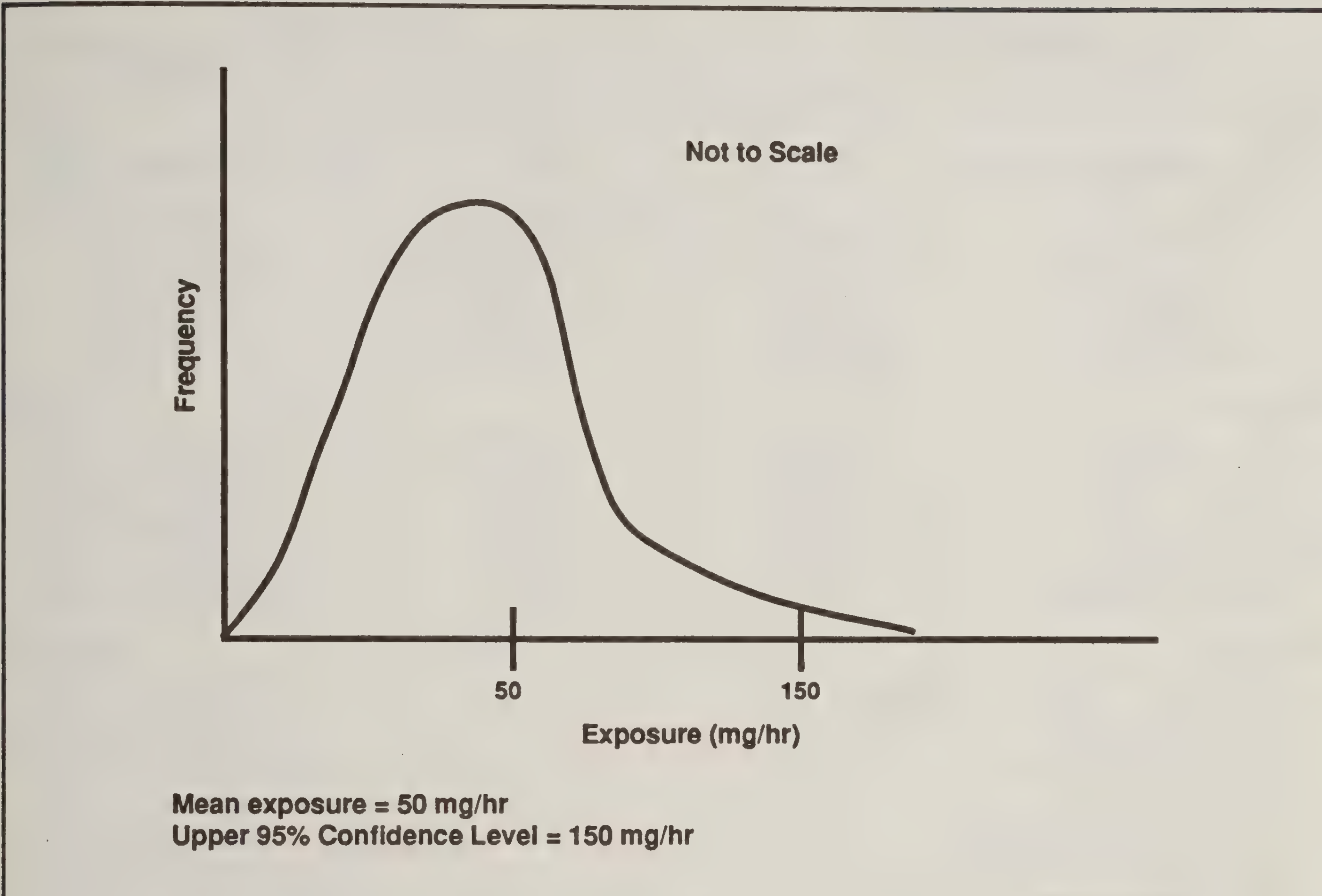
To calculate public exposures, the typical case was assumed to be exposure to drift at a distance of 500 feet from the boundary of the spraying area, while the extreme exposures were based on exposure 100 feet from the boundary. (See table B3-3 for the routine exposures and the assumptions used in calculating these exposures.)

Figure B3-1 illustrates an example of the upper limit of the 95-percent confidence interval. The figure is based on an assumed situation in which a group of workers was exposed to an insecticide. Insecticide concentrations in body tissues were later measured. The results of the tissue analysis and the exposure information yield an effective exposure, expressed in figure B3-1 in milligrams of insecticide per hour (mg/hr). Because a large population of workers was exposed, a Gaussian distribution of the ranges of their exposures is created. In figure B3-1, the average worker insecticide exposure is 50 mg/hr. A range of exposures was measured, with some being greater than 50 mg/hr and others less than 50 mg/hr. By referring to the distribution and using the statistical analyses that often accompany these distributions, it would be found that at an extreme, 95 percent of the time the worker exposure to insecticide is less than 150 mg/hr—an amount that defines the upper limit of the 95-percent confidence interval as used in this exposure analysis, where applicable. It is this measure of exposure at the upper limit of the 95-percent confidence interval that is used to define the worker exposures in the worst case.

**Exposures to Workers**

The calculated exposures to workers from the insecticides malathion, azinphos-methyl, diflubenzuron, and methyl parathion and from xylene

**Figure B3-1. Example of Upper 95-Percent Confidence Level**




(an inert ingredient of methyl parathion) are shown in tables B3-5 through B3-9.

### Exposures to Pilots and Mixer/Loaders

Exposures to pilots and mixer/loaders were estimated from a field monitoring study (Atallah et al., 1982). EPA's Exposure Assessment Branch has used this study to estimate worker exposures (Reinert and Severn, 1985). In this study, respiratory exposures were measured with air sampling tubes and a calibrated air sampler attached at the waist. Dermal exposures were measured from hand rinses and denim patches attached to the face, the back of the neck, the front of the neck, the "V" of the upper chest, and the forearms. For this analysis, the dermal and respiratory exposures (reported as micrograms (µg) per 8-hour work-day in this study) were averaged for each of the worker categories and adjusted to an average application rate of 1 pound active ingredient per acre (lb a.i./acre). The average dermal exposures were

**Table B3-5. Control Program—Calculated Exposures to MALATHION**

| Exposure scenario | Dose (mg/kg/day) | |
|---|---|---|
| | Typical | Extreme |
| **Public[a]:** | | |
| Dermal and inhalation drift | 0.00 | 0.00292 |
| Dietary— | | |
| Water | 0.0000703 | 0.00351 |
| Fish | 0.0000434 | 0.0568 |
| Venison | 0.000978 | 0.00171 |
| Legumes | 0.000306 | 0.0153 |
| Berries | 0.000153 | 0.00763 |
| **Workers[b]:** | | |
| Pilot | 0.00453 | 0.00939 |
| Mixer/loader | 0.01 | 0.0283 |
| Observer | 0.0651 | 0.509 |
| Monitoring team | 0.000221 | 0.000344 |
| Hiboy applicator | 0.124 | 1.13 |
| Mist blower applicator | 0.123 | 0.247 |
| **Accidents:** | | |
| Spill of concentrate | | 242.00 |
| Broken hose | | 242.00 |
| Immediate field entry | | 0.00035 |
| Spray at 25 feet—adult | | 0.0294 |
| Direct spray—adult | | 0.0372 |
| Drink reservoir water/release | | 0.0744 |
| Eating berries—direct spray | | 0.0134 |
| Eating legumes—direct spray | | 0.0267 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.

[b] Worker exposures: typical is based on average dose; extreme is based on upper 95-percent confidence level.

**Table B3-6. Control Program—Calculated Exposures to AZINPHOS-METHYL**

| Exposure scenario | Dose (mg/kg/day) | |
|---|---|---|
| | Typical | Extreme |
| **Public**[a]: | | |
| Dermal and inhalation drift | 0.00 | 0.000681 |
| Dietary— | | |
| Water | 0.0000141 | 0.00075 |
| Fish | 0.00 | 0.0131 |
| Venison | 0.000204 | 0.000358 |
| Legumes | 0.0000612 | 0.00327 |
| Berries | 0.0000306 | 0.00163 |
| **Workers**[b]: | | |
| Pilot | 0.00176 | 0.00382 |
| Mixer/loader | 0.00391 | 0.016 |
| Observer | 0.014 | 0.130 |
| Monitoring team | 0.000572 | 0.000675 |
| Hiboy applicator | 0.275 | 2.19 |
| Mist blower applicator | 0.187 | 0.401 |
| **Accidents:** | | |
| Spill of concentrate | | 101 |
| Broken hose | | 101 |
| Immediate field entry | | 0.00068 |
| Spray at 25 feet—adult | | 0.01 |
| Direct spray—adult | | 0.0137 |
| Drink reservoir water/release | | 0.016 |
| Eating berries—direct spray | | 0.00286 |
| Eating legumes—direct spray | | 0.00571 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.

[b] Worker exposures: typical is based on average dose; extreme is based on upper 95-percent confidence level.

**Table B3-7. Control Program—Calculated Exposures to DIFLUBENZURON (Eradication Only)**

| Exposure scenario | Dose (mg/kg/day) | |
|---|---|---|
| | Typical | Extreme |
| **Public**[a]: | | |
| Dermal and inhalation drift | 0.00 | 0.00033 |
| Dietary— | | |
| Water | 0.00000937 | 0.000375 |
| Fish | 0.00 | 0.0164 |
| Venison | 0.000104 | 0.000182 |
| Legumes | 0.0000408 | 0.00163 |
| Berries | 0.0000204 | 0.000816 |
| **Workers**[b]: | | |
| Pilot | 0.000561 | 0.00122 |
| Mixer/loader | 0.00124 | 0.00367 |
| Observer | 0.00698 | 0.0638 |
| Monitoring team | 0.000406 | 0.000427 |
| Hiboy applicator | 0.173 | 1.38 |
| Mist blower applicator | 0.113 | 0.246 |
| **Accidents:** | | |
| Spill of concentrate | | 66.2 |
| Broken hose | | 16.5 |
| Immediate field entry | | 0.000427 |
| Spray at 25 feet—adult | | 0.00377 |
| Direct spray—adult | | 0.00450 |
| Drink reservoir water/release | | 0.00418 |
| Eating berries—direct spray | | 0.00143 |
| Eating legumes—direct spray | | 0.00286 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.

[b] Worker exposures: typical is based on average dose; extreme is based on upper 95-percent confidence level.

**Table B3-8. Control Program—Calculated Exposures to METHYL PARATHION**

| Exposure scenario | Dose (mg/kg/day) | |
|---|---|---|
| | Typical | Extreme |
| **Public**[a]: | | |
| Dermal and inhalation drift | 0.00 | 0.00127 |
| Dietary— | | |
| Water | 0.0000281 | 0.0015 |
| Fish | 0.00 | 0.512 |
| Venison | 0.000416 | 0.000728 |
| Legumes | 0.000122 | 0.00653 |
| Berries | 0.00000612 | 0.00327 |
| **Workers**[b]: | | |
| Pilot | 0.00225 | 0.00486 |
| Mixer/loader | 0.00497 | 0.0147 |
| Observer | 0.0279 | 0.255 |
| Monitoring team | 0.000269 | 0.000419 |
| Hiboy applicator | 0.173 | 1.38 |
| Mist blower applicator | 0.126 | 0.266 |
| **Accidents:** | | |
| Spill of concentrate | | 63.3 |
| Broken hose | | 31.7 |
| Immediate field entry | | 0.000427 |
| Spray at 25 feet—adult | | 0.0151 |
| Direct spray—adult | | 0.0180 |
| Drink reservoir water/release | | 0.0080 |
| Eating berries—direct spray | | 0.00571 |
| Eating legumes—direct spray | | 0.0114 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.

[b] Worker exposures: typical is based on average dose; extreme is based on upper 95-percent confidence level.

Table B3-9. Control Program—Calculated Exposures to XYLENE

| Exposure scenario | Dose (mg/kg/day) | |
|---|---|---|
| | Typical | Extreme |
| **Public**[a]: | | |
| Dermal and inhalation drift | 0.00 | 0.0000597 |
| Dietary— | | |
| Water | 0.000000746 | 0.0000375 |
| Fish | 0.000000169 | 0.000787 |
| Venison | 0.0000104 | 0.0000728 |
| Legumes | 0.00000333 | 0.000163 |
| Berries | 0.00000166 | 0.0000816 |
| **Workers**[b]: | | |
| Pilot | 0.000225 | 0.000486 |
| Mixer/loader | 0.000497 | 0.00147 |
| Observer | 0.00139 | 0.0125 |
| Monitoring team | 0.000427 | 0.000427 |
| Hiboy applicator | 0.173 | 1.38 |
| Mist blower applicator | 0.110 | 0.242 |
| **Accidents:** | | |
| Spill of concentrate | | 12.7 |
| Broken hose | | 12.7 |
| Immediate field entry | | 0.000427 |
| Spray at 25 feet—adult | | 0.000541 |
| Direct spray—adult | | 0.00164 |
| Drink reservoir water/release | | 0.00320 |
| Eating berries—direct spray | | 0.0000571 |
| Eating legumes—direct spray | | 0.00114 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.

[b] Worker exposures: typical is based on average dose; extreme is based on upper 95-percent confidence level.

3,009 µg/8 hours for pilots and 6,774 µg/8 hours for mixer/loaders. The upper limit of the 95-percent confidence interval from this study lists the pilot dermal exposure as 4,391 µg/8 hours and the mixer/loader exposure as 13,466 µg/8 hours. For the inhalation exposure to these same workers, Attalah et al. (1982) presented the typical pilot and mixer/loader exposures as 13.4 µg/8 hours and 18.9 µg/8 hours, respectively; the upper limits of the 95-percent confidence interval for extreme scenarios were 14.6 µg/8 hours and 23.8 µg/8 hours, respectively.

Typical doses to workers for the National Boll Weevil Cooperative Control Program were calculated using the average adjusted exposure values described above and the application rate and dermal penetration rate of each chemical. The exposures also were adjusted for the number of hours worked per day. Workers were assumed to wear no special protective clothing and have a body weight of 70 kilograms (kg) (about 150 pounds). (Protective clothing is prescribed for the handling of azinphos-methyl and methyl parathion; no such restrictions exist for diflubenzuron and malathion.) For extreme exposures, the upper limit of the 95-percent confidence interval (from the Attalah et al., 1982) study was used. Extreme exposures also included the longer workday (12 hours instead of 8 hours).

Exposures from routine operations and from accidental direct spraying were based on the planned application rates in pounds per acre. Exposures to insecticide drift were based on the aerial spray drift model described in section B8 of this appendix. It was assumed that the wind blows perpendicularly to the flight path of the application aircraft at a velocity of 10 mph.

Dermal penetrations of malathion and azinphos-methyl were estimated to be 8.2 percent and 15.9 percent, respectively (Feldmann and Maibach, 1974). The dermal penetrations for methyl parathion, diflubenzuron, and xylene were assumed to be 10 percent (USDA, 1984). These penetration estimates are expressed as fixed percentages, based on dermal exposure studies that occurred over extended time periods. Because dermal penetration is time dependent, if a person washes within the first few hours after exposure, penetration will actually be less than assumed in this analysis. Penetration through clothing was assumed to be 30 percent as great as through bare skin, based on work by Newton and Norris (1981) on phenoxy herbicides.

An example of the typical exposure to malathion for a pilot is given in equation B3.1:

$$\begin{aligned}&(8\ \mathrm{hr/day}/8) \times 1.17\ \mathrm{lb\ a.i./acre} \times [(13.4\ \mu g \times 0.001\ \mathrm{mg}/\mu g)\\&+ (3{,}009\ \mu g \times 0.082 \times 0.001\ \mathrm{mg}/\mu g)])\ /70\ \mathrm{kg}\\&= 0.00435\ \mathrm{mg/kg/day}\end{aligned} \qquad \text{(Equation B3.1)}$$

In this calculation, it is assumed that pilots are exposed for 8 hours per day, that malathion is applied at 1.17 lb a.i./acre, and that the dermal penetration of malathion is 0.082. The resultant mass of malathion from this calculation is converted from micrograms to milligrams to produce a result that is uniform with the standard toxicology literature when making reference to exposure doses.

Dermal doses to workers from accidental spills were calculated assuming that one-half liter of insecticide concentrate (or mix for diflubenzuron and methyl parathion because they are received as powders) is retained—90 percent on the worker's clothing and 10 percent on the worker's skin. This amount of liquid is sufficient to wet most of the worker's body. An example of the accidental dose of malathion received by a worker is calculated in equation B3.2:

$$(9.3 \text{ lb/gal}) \times (119{,}839 \text{ mg/L})/(\text{lb/gal})) \times (0.5 \text{ L}) \times (0.082) \times ((0.9 \times 0.3) + 0.1)/70 \text{ kg} = 242 \text{ mg/kg} \qquad \text{(Equation B3.2)}$$

The density of liquid malathion is 9.3 lb/gal, and the factor of 119,839 converts pounds per gallon to milligrams per liter (mg/L).

### Exposures to Ground Application Personnel

Ground application personnel exposures during the application of pesticides with ground equipment have also been measured in field studies similar to those described above for pilots and mixer/loaders. The results of these studies are collected and presented by Reinert and Severn (1985). People operating hiboy ground sprayers are expected to receive 24.4 mg/hr according to the studies presented, with no specified application rate. For an extreme scenario, the dose would be 130 mg/hr, again with no specified application rate. For the purposes of this exposure analysis, it is assumed that these numbers are dependent on an application rate of 1 lb a.i./acre and are adjusted accordingly when other application rates are considered. For illustrative purposes, it is assumed that malathion is applied at 1.17 lb a.i./acre, a working day is 8 hours, and the dermal penetration is 8.2 percent. The personnel study assumed an exposed body surface of 3,000 $cm^2$. This analysis assumes 2 $ft^2$ of exposed body surface. The factor 0.0929 $m^2/ft^2 \times 10{,}000\ cm^2/m^2$ converts square feet to square centimeters.

$$(24.4 \text{ mg/hr}/1 \text{ lb a.i./acre}) \times 8 \text{ hr/day} \times 1.17 \text{ lb a.i./acre} ((2 \text{ ft}^2 \times 0.0929 \text{ m}^2/\text{ft}^2 \times 10{,}000 \text{ cm}^2/\text{m}^2)/3{,}000 \text{ cm}^2) \times 0.082/70 \text{ kg} = 0.142 \text{ mg/kg/day} \qquad \text{(Equation B3.3)}$$

In the extreme scenario, where the hourly dose is 130 mg/hr and the exposure period is 12 hours per day, the extreme dose for a hiboy operator is as follows:

$$(130 \text{ mg/hr}/(1 \text{ lb a.i./acre}) \times 12 \text{ hr/day} \times 1.17 \text{ lb a.i./acre} \times 0.082)/70 \text{ kg} = 2.14 \text{ mg/kg/day}$$

(Equation B3.4)

For ground application personnel who use mist blowers, the Reinert and Severn (1985) study provides exposure data that depend on the application rate. Twenty-three separate data points were analyzed using a least-squares linear regression. The resulting equation for mist blower operators receiving a typical dose appears as shown in equation B3.5.

$$\text{mg/kg/day} = \text{DPR} \times \text{hrs/day} \times 2 \text{ ft}^2 \times 0.0929 \text{ m}^2/\text{ft}^2 \times ((10{,}000 \text{ cm}^2/\text{m}^2)/3{,}000 \text{ cm}^2) \times [15.32 \text{ mg/hr} + (5.02 \text{ (mg/hr)}/(1 \text{ 1b a.i./acre})) \times \text{app. rate in lb a.i./acre}]/\text{body weight in kg}$$

(Equation B3.5)

In this equation, DPR is the dermal penetration rate. The personnel study assumed an exposed body surface of 3,000 $cm^2$. This analysis assumes 2 $ft^2$ of exposed body surface. The factor 0.0929 $m^2/ft^2 \times$ 10,000 $cm^2/m^2$ converts square feet to square centimeters. The factor 15.32 mg/m is the typical intercept of the regression equation, and 5.02 (mg/hr)/(lb a.i./acre) is the calculated slope.

Using malathion again as an example, by inserting a typical workday of 8 hours and an application rate of 1.17 lb a.i./acre, the calculation yields an exposure to mist blower operators of 0.123 mg/kg/day of malathion.

In the extreme case, the longer daily exposure period is considered (12 hours), and equation B3.5 is altered. Based on an interpretation of the results provided by Reinert and Severn (1985) and using their 95-percent confidence interval, the upper limit exposure could be calculated as shown in equation B3.6:

$$\text{mg/kg/day} = \text{DPR} \times 0.0929 \text{ ft}^2/\text{m}^2 \times 2 \text{ ft}^2 \times ((10{,}000 \text{ cm}^2/\text{m}^2)/3{,}000 \text{ cm}^2) \text{ hr/day} \times [22.5 \text{ mg/hr} + (5.02 \text{ (mg/hr)}/(\text{lb a.i./acre}) \times \text{app. rate in lb a.i./acre}]/\text{body weight in kg} = 0.247 \text{ mg/kg/day for a 12 hr workday}$$

(Equation B3.6)

The factors used in this equation are identical to those in equation B3.5, with the exception of 22.5 mg/hr, which is the extreme exposure intercept of the regression equation.

### Exposures to Observers

Observers, who include aircraft flagging personnel, and all other personnel near the spraying operations, were assumed to receive dermal and inhalation doses. Dermal exposure was calculated for 2 $ft^2$ of exposed skin. The dermal penetration rates and drift deposition values that were previously described were used.

Inhalation exposure was calculated based on air sampler data collected during the field trials of Yates et al. (1978). The worker's breathing rate was assumed to be 16 L/min (1 $m^3$/hr), which represents an average for an adult. This value is conservative, regardless of activity (EPA, 1988). Inhaled doses were calculated assuming that spray droplets are inspired by people with the same efficiency as by air samplers. One hundred percent of the inspired droplets was assumed to be retained and absorbed. Doses were adjusted to reflect the typical and worst case number of hours a worker would be exposed.

An example calculation for an observer standing 100 feet from aerial application of malathion, working a typical day of 8 hours, would be calculated as shown in equation B3.7. The factor of 0.0929 converts the skin area from square feet to square meters. The amount of insecticide that drifts and is deposited on the skin is calculated in section B8 of this appendix; at 100 feet, the amount is 1.5 mg/$m^2$. The amount of drift that could be inhaled at a distance of 100 feet is 0.000378 mg/L. Again, the dermal penetration rate of malathion is estimated to be 0.082, and the average worker body weight is 70 kg. Using these factors, equation B3.7 shows how the dose that an observer may receive at a distance of 100 feet from the edge of a swath where malathion is aerially applied is calculated:

$$[(1.5 \text{ mg/m}^2 \times 2 \text{ ft}^2 \times 0.0929 \text{ m}^2/\text{ft}^2 \times 0.082) +$$
$$(16 \text{ L/min} \times 60 \text{ min/hr} \times 8 \text{ hr/day} \times 0.000378 \text{ mg/L})]/70 \text{ kg}$$
$$= 0.0418 \text{ mg/kg/day}$$

(Equation B3.7)

### Exposures to the Environmental Monitoring Team

The environmental monitoring team may receive doses of insecticides from contact with sprayed vegetation. Team members are not expected to receive a direct dermal drift dose or an inhalation dose. It is assumed that the monitoring team will enter a field before the prescribed reentry period stated on the insecticide label. The emphasis on monitoring is the collection of samples outside the spray area. The prescribed reentry periods, which vary among insecticides, are presented in table B3-10 for the insecticides studied in this exposure assessment.

Studies by Lavy et al. (1980) were used to calculate indirect dermal exposure resulting from contact with foliage that has surface residues of pesticides. Exposure to phenoxy herbicides was measured on people

**Table B3-10. Label-Prescribed Reentry Periods**

| Pesticide | Waiting period (days) |
|---|---|
| Azinphos-methyl | 2 |
| Diflubenzuron | 0 |
| Malathion | 0 |
| Methyl parathion | 2 |

who obtained herbicide doses through incidental contact with sprayed foliage. Cloth patch samplers were attached to a person who walked through a treated area. The residues were less than the detection limit of 0.01 mg/100 $cm^2$ patch, but in this analysis, a conservative assumption was made that the residues were at the detection limit. The area of clothing coming into contact with foliage is assumed to be 40 percent of the assumed body surface area of 13,600 $cm^2$. It is assumed that 30 percent of the insecticide on the clothing penetrates to the skin. Additionally, it is assumed that 10 percent of the body surface area is bare skin and comes into contact with sprayed foliage. These factors are considered in equation B3.11.

It was assumed that contact by the environmental monitoring team with sprayed foliage would occur shortly after spraying. Therefore, degradation of the insecticide was considered. The degradation half-lives of the various insecticides and xylene are presented in section B8 of this appendix. These values are used to predict the amount of insecticide that might remain on foliage after some time period, which, in this situation, was assumed to be 2 days. While the label reentry periods are not uniformly 2 days, it was assumed that this waiting period was reasonable, and it is used in the determination of environmental evaluation team exposures. In the extreme scenario, the waiting period was reduced to 1 hour. In the consideration of accidental scenarios, it is assumed that field reentry occurs immediately after spraying. It is also assumed that only 60 percent of the insecticide residue available on the leaf surface is capable of being dislodged from the leaf and transferred to the person in contact with the leaf. Consideration of all the above factors gives the dermal exposure from contact with sprayed vegetation. First, the quantity of residue initially available ($R_o$) is calculated, in this case for malathion. Malathion is applied at a rate of 1.17 lb a.i./acre, and the factor of 0.01123 converts pounds per acre to milligrams per square centimeter. Equation B3.8 also considers that only 60 percent of the malathion residue can be transferred. The equation is as follows:

$$R_o = (1.17 \text{ lb a.i./acre}) \times (0.01123 \text{ mg/cm}^2/\text{lb a.i./acre}) \times 0.6 = 0.00788 \text{ mg/cm}^2$$

(Equation B3.8)

After the initial quantity of malathion available for transfer is calculated, it is necessary to calculate the environmental degradation rate, $K_r$, in units of reciprocal days, $d^{-1}$. This is based on the 3-day environmental half-life of malathion. This calculation is as follows:

$$K_r = (-\ln 0.5)/3 \text{ days} = 0.231 \text{ d}^{-1}$$

(Equation B3.9)

Next, the amount of malathion available to be transferred, R, after a period of 2 days, t, is calculated in equation B3.10:

$$R = R_o\, e^{-(Kr \times t)} = 0.00788 \text{ mg/cm}^2 \times e^{-(0.231/\text{day} \times 2 \text{ days})} = 0.00496 \text{ mg/cm}^2$$

(Equation B3.10)

Finally, the environmental evaluation team member dose is calculated, as shown in equation B3.11. This calculation depends on the quantity of insecticide available for contact transfer after a waiting period of 2 days and the initial quantity of insecticide available; the dermal penetration rate of 0.082 for malathion; the surface area of an adult, 13,600 $\text{cm}^2$; the clothing detection limit of 0.01 mg/100 $\text{cm}^2$; the area of the clothing in contact plus the penetration through the clothing; the area of bare skin open to contact; and the body weight, 70 kg, of the individual. This equation is shown below:

$$\text{Dose in mg/kg/day} = [(0.00496 \text{ mg/cm}^2/0.00788 \text{ mg/cm}^2) \times 0.082 \times 13{,}600 \text{ cm}^2 \times (0.01 \text{ mg}/100 \text{ cm}^2) \times ((0.4 \times 0.3) + 0.1)]/70 \text{ kg} = 2.21 \times 10^{-4} \text{ mg/kg/day} = 0.000221 \text{ mg/kg/day}$$

(Equation B3.11)

## Conservative Estimation of Worker Doses

As described above, this risk assessment estimates two separate dose levels for each category of worker in routine operations—typical and extreme. The typical dose is based on combining average nominal doses from field studies with scenario conditions that are typical for boll weevil control operations in the program areas.

However, the typical dose estimates are higher than those that might occur in actual operations. The doses are based on field-study doses of applicators who wore no special protective clothing or devices. In many of the proposed control program operations, workers will be required to wear protective gear, depending on the insecticide being

applied. While malathion and diflubenzuron do not require any special protective clothing, methyl parathion requires double-layered protective clothing and respirators. The use of human flaggers is not allowed with methyl parathion because flaggers generally do not wear protective clothing and because of the potentially high dermal doses of insecticide that they could receive from direct spray.

For extreme scenarios, the worker doses used to calculate the exposures are not the average dose measured but the dose at the upper limit of the 95-percent confidence interval; the extended working period is also considered. This means that there is only 1 chance in 40 that a worker in the same field operation under the same conditions of terrain, weather, and equipment would receive a dose higher than the specified dose. When this upper limit dose is combined with the assumptions of a longer working day or a shorter reentry waiting period, extremely high doses are estimated that are unlikely to occur under actual operational conditions because the probability of these events occurring at the same time is very low.

In addition, the field studies may also take into account normal operational errors, such as the following:

- Errors of measurement during manufacturing and formulation
- Errors of measurement during field mixing
- Excessive swath overlap during application

### Exposures to Members of the Public

The calculated exposures to members of the public from the four insecticides and xylene during control programs are also presented in tables B3-5 through B3-9.

#### Dermal Exposures

Dermal exposures were estimated for typical and extreme scenarios for a 70-kg adult wearing short sleeves and trousers, assuming that 2 $ft^2$ of skin is covered with insecticide at the drift deposition rate at distances of 500 and 100 feet. Because dermal doses were calculated similarly to those calculated previously for the dermal exposures of observers receiving drift, the calculations will not be repeated here.

This method is likely to overestimate exposures because spray droplets, depending on their size and the wind velocity, tend to be carried around obstructions rather than land on their surface (see Golovin and Putnam, 1962). Very small droplets, typical of ultra-low-volume sprays, are the most likely to be carried around obstructions.

Dermal exposures for accidents were calculated by assuming that an adult is directly sprayed at the maximum application rate and that 2 $ft^2$ of skin are uncovered.

## Inhalation Exposures

Exposures from inhaling insecticide vapors and droplets were calculated for members of the public by manipulating the AGDISP drift exposure. AGDISP results are given as the mass of drift per unit area, while inhalation exposures require the mass of insecticide in a unit volume of air. The fraction of the total droplets measuring less than 56 microns was calculated from the AGDISP results. Thirty microns is the maximum size of a particle that can be respired into the nasopharyngeal region. Only particles less than 5 microns can be respired into the trachea, and only particles less than 1 micron can be respired into the alveolar (the deepest) region of the lungs (Menzel and Amdur, 1986) Thus, the analysis of all droplets less than 56 microns is conservative. This mass of insecticide was then assumed to be distributed throughout the air column under the aircraft. The results of this conversion were expressed in units of milligrams of insecticide per liter of air (mg/L). Doses to humans were then calculated by assuming that a person breathes at a rate of 1 $m^3$/hr and is exposed for a period of 0.5 hr. AGDISP results indicate that most droplets of 56 microns settle out of the air within 3 minutes; the selection of a 30-minute exposure time is conservative.

## Oral Exposures

All oral exposures were calculated by assuming that no degradation occurs between the time spraying occurs and the time the contaminated item is ingested.

**Residues on Plants**. Insecticide residues on plants on treated sites were estimated based on factors reported by Hoerger and Kenaga (1972) from a large number of field measurements. These factors predict plant residues in ppm based on the insecticide application rate in pounds per acre. Residue estimates were calculated assuming no insecticide degradation, which reflects conditions immediately after insecticide application. As with the methodology in the Hoerger and Kenaga (1972) study, the plants were classified into broad groups based on vegetative yield, surface-to-mass ratio, and plant interception factors. The residues estimated for each type of plant are intended to represent realistic, yet relatively high, estimates.

Offsite plant residues were calculated first for grasses, based on spray drift data discussed in section B8 of this appendix, and by using factors reported by Hoerger and Kenaga (1972) to relate spray deposition on young wheat plants to that on sampling devices. The deposition was also estimated for other plant groups, such as berries and legumes, by using the same relative factors.

An example calculation using the Hoerger and Kenaga (1972) factors is presented below (for the purposes of this presentation, it is assumed that the application rate of malathion is equivalent to 1.17 lb a.i./acre):

Insecticide on wheat in ppm = (92 ppm/lb a.i./acre) × 1.17 lb a.i./acre = 108 ppm

(Equation B3.12)

Equation B3.12 demonstrates the estimated residue of malathion on wheat if the wheat was directly sprayed. If wheat was not directly sprayed, the estimated malathion residue would be different. As an example, to calculate malathion deposition on wheat at 100 feet, the fraction that drifts must be considered in equation B3.12. At 100 feet, a figure of 2.44 $mg/m^2$ of malathion is predicted to be deposited from drift. Originally there were 137 $mg/m^2$ available to drift. Therefore, the malathion that might be present on wheat at 100 feet is calculated in equation B3.13:

Insecticide on wheat (ppm) = (92 ppm/lb. a.i./acre) × (1.17 lb a.i./acre) × (2.44 $mg/m^2$)/(137 $mg/m^2$) = 1.92 ppm

(Equation B3.13)

Insecticide doses to individuals were calculated by assuming that they consume 500 grams (0.5 kg or 1.1 pounds) of contaminated berries or legumes grown at distances of 100 and 25 feet from the spray site. Doses were calculated for accidental exposures assuming that legumes and berries received direct spray at the full application rate.

**Residues in Water.** Doses were calculated assuming humans drank water from several contaminated sources. A shallow (2-foot deep) source was assumed to receive drift at 500 feet downwind from the sprayed area. No degradation or adsorption to sediments was assumed to occur before drinking 2 liters (approximately 2 quarts) of water. The concentrations in water were calculated as simple dilutions. For extreme exposures, the body of water was assumed to be 100 feet offsite. The actual residues in water would be less under more favorable spray conditions, at greater distances, or with deeper water bodies. Degradation or adsorption to sediments would also reduce insecticide residues. A calculation of the quantity of malathion found in a pond 2-feet deep receiving drift at 10 $mg/m^3$ is presented in equation B3.14. In this equation, the factor of 0.3048 converts feet to meters, and 0.001 converts liters (L) to cubic meters ($m^3$). The water concentration of malathion is calculated as follows:

$$(10\ mg/m^2 \times 0.001\ m^3/L)/(2\ ft \times 0.3048\ m/ft) = 0.0164\ mg/L \text{ of malathion}$$

(Equation B3.14)

For a 70-kg person drinking 2 liters of contaminated water per day, the dose is calculated as shown below:

Malathion dose (mg/kg/day) =
(0.0164 mg/L × 2 L/day)/70 kg = 0.000469 mg/kg/day

(Equation B3.15)

Accidental drinking water exposures also were calculated by dilution of a spill from an aircraft load of 80 gallons into a 16-acre reservoir that is 2 meters deep. The methodology of the calculation is similar and will not be repeated.

**Residues in Fish**. Typical oral doses from eating fish were calculated by assuming that the fish is taken from a body of water (pond) 2 feet deep, receiving drift 100 feet downwind from a sprayed area. The fish were assumed to have residues resulting from equilibration with the water at a bioconcentration factor (BCF), in L/kg, of 40 for azinphos-methyl, 100 for diflubenzuron (Veith et al., 1980), 37 for malathion (American Cyanamid, 1986), 87 for methyl parathion (Environmental Fate Database, 1990), and 12 for xylene. The BCF for azinphos-methyl was calculated based on the correlation of bioconcentration factor to the organic carbon partition coefficient ($K_{oc}$) of the particular compound. This equation (from Kenaga and Goring, 1978; as cited in Lyman et al., 1982) is presented below:

$$\log BCF = 1.119 \log K_{oc} - 1.579$$

(Equation B3.16)

Equation B3.16 is applicable to a wide range of chemicals and is well correlated with the octanol-water partition coefficient. The organic carbon partition coefficient, as retrieved from the Hazardous Substances Databank (NLM, 1988), is 700 for azinphos-methyl, 14,000 for methyl parathion, and 6,790 for diflubenzuron.

To determine the BCF for xylene, the equation used (from Kenaga and Goring, 1978; as cited in Lyman et al., 1982) depends on the solubility of p-xylene (198 mg/L) (Verscheuren, 1983):

$$\log K_{oc} = (0.55 \times \log 5) + 3.64$$

(Equation B3.17)

For all scenarios, it was assumed that 0.5 kg of fish was eaten. Extreme exposures were estimated assuming a pond 2 feet deep that received a direct spray of insecticide.

Using the water concentration of malathion calculated in equation B3.14, an example calculation is presented below that uses the BCF. The assumptions for equations B3.14 and B3.18 are that the depth of the pond is 2 feet and that the drift deposition on the surface of the pond is 10 mg/m$^2$. The BCF for malathion is 37. The malathion dose (mg/kg/day) is as shown in equation B3.18.

$$(0.0164 \text{ mg/L} \times 37 \text{ L/kg} \times 0.5 \text{ kg/day})/70 \text{ kg} = 0.00433 \text{ mg/kg/day}$$

(Equation B3.18)

**Residues in Game Animals.** Insecticide residues were calculated for a 120-lb (54.5-kg) deer. The entire body surface area of the animal was assumed to be exposed to spray drift. The body surface area was assumed to be a function of the body weight, according to the following equation:

$$\text{Body surface area in m}^2 = 0.001 \times (1{,}000 \text{ g/kg} \times \text{body weight in kg})^{2/3}$$

(Equation B3.19)

In equation B3.19, the deer weighs 54.5 kg, 0.001 is a conversion factor to $m^2$, and the body surface area is equal to 1.44 $m^2$. The fraction of the body in contact with vegetation was assumed to be 0.39. The penetration rate of the insecticides through mammalian skin was assumed to be the same as for human skin.

The deer was assumed to get an oral dose of insecticide through its diet. The oral dose was based on the assumption that the deer consumed 2.45 kg/day of forage (food items) and 4.0 L of water. Contamination of the forage was calculated similarly to the way contamination was calculated for berries. The contamination of the ingested water was calculated assuming that the water was 2 feet deep. It was assumed that both the deer and its forage received drift from a distance of 25 feet and from a direct spray.

The concentration of insecticide in game meat was calculated by adding the animal's doses from the dermal and oral routes of exposure and by assuming that 10 percent of that total dose was retained in the animal meat. This is similar to the method used in the exposure analysis of USDA (1984). Insecticide doses to humans were calculated by assuming that a person eats 0.5 kg of venison per day.

### Conservative Estimation of Public Doses

In determining doses for members of the general public, certain situations were assumed to occur to ensure that these doses were not underestimated. First, the smaller spray particles in offsite drift were assumed to land on the body, although, in fact, they tend to move around rather than land on curved surfaces. Second, it is assumed that the insecticide does not degrade at all nor bind with any material, such as vegetation, to make it biologically unavailable to humans. Thus, doses that may actually occur from any activity involving contact with treated vegetation would be less than estimated here.

The extreme doses to the public can be considered the highest possible doses for routine spray operations because they are calculated in scenarios that combine unlikely factors and events. For example, it is assumed that a member of the public consumes larger than normal quantities of foods or is present near the spraying operations. As a result, no member of the public should get a dose that is any higher than the dose estimated in the extreme scenario, except in the case of accidents.

### Lifetime Doses to Workers and the Public

Doses that workers and the public could receive over a lifetime (assumed to be 70 years) are used to calculate the risks of getting cancer. The doses used in calculating the cancer risk to workers were derived by combining information on the number of days per year an individual worker may be exposed to an insecticide from a particular application method and estimates of the expected daily dose and the number of years of employment. Expected daily doses were calculated by assuming that the worker receives the extreme dose 10 percent of the time and receives the typical dose 90 percent of the time for all routine scenarios. Workers are assumed to be employed in insecticide application for 30 years. Average numbers of exposures per lifetime (70 years) were multiplied by the expected daily doses for each scenario to derive realistic lifetime doses. The predicted cancer risks to application personnel and the public under boll weevil eradication and suppression programs are presented in tables B3-11 through B3-15.

Lifetime exposures to the public from the insecticides were derived by assuming 19 exposures in a lifetime for each exposure scenario under the boll weevil eradication program and assuming that 90 percent of these exposures were typical and that 10 percent were worst case. The assumption of 19 exposures was based on the total number of exposures a person might receive over the period of the National Boll Weevil Cooperative Control Program—assuming a reasonable scenario of 4 applications of insecticide to a field the first year of the program, 8 applications the second year, 4 applications the third year, 2 applications the fourth year, and a single application the fifth year, with no subsequent applications or exposures. Under the boll weevil suppression exposure, it was assumed that a person typically received 5, 7, 5, 4, and 7 doses repeated over a 30-year interval, for a total of 174 exposures.

To provide an analysis of the public cancer sensitivity to these insecticides, extreme cases were also calculated. For the eradication program, one extreme scenario was used. In this scenario, the extreme number of applications were used: 5 the first year, 25 the second year, 12 the third year, 6 the fourth year, 3 the fifth year, and a single application the sixth and seventh years, for a total of 53 exposures. In a less extreme cancer risk analysis, 35 total exposures were assumed, based on the application scenario of 5 applications the first year, 16 the second year, 8 the third year, 4 the fourth year, and a single application the fifth and sixth years.

**Table B3-11. Predicted Lifetime Cancer Risk for MALATHION in an Eradication Program**

| Exposure scenario | Risk | | |
|---|---|---|---|
| | Realistic | Intermediate | Maximum |
| **Public:** | | | |
| Dermal and inhalation drift | 0.000000000816 | 0.0000000015 | 0.0000000228 |
| Dietary— | | | |
| Water | 0.00000000116 | 0.00000000213 | 0.00000000323 |
| Fish | 0.0000000107 | 0.0000000197 | 0.0000000299 |
| Venison | 0.00000000296 | 0.00000000545 | 0.00000000826 |
| Legumes | 0.0000000385 | 0.0000000709 | 0.000000107 |
| Berries | 0.0000000193 | 0.0000000355 | 0.0000000537 |
| **Workers:** | | | |
| Pilot | 0.00000456 | | |
| Mixer/loader | 0.0000108 | | |
| Observer | 0.0000490 | | |
| Monitoring team | 0.00000021 | | |
| Hiboy applicator | 0.000217 | | |
| Mist blower applicator | 0.000123 | | |
| **Accidents:** | | | |
| Spill of concentrate | 0.0000481 | | |
| Broken hose | 0.0000481 | | |
| Immediate field entry | 0.0000000000516 | | |
| Spray at 25 feet—adult | 0.00000000433 | | |
| Direct spray—adult | 0.00000000439 | | |
| Drink reservoir water/release | 0.0000000110 | | |
| Eating berries—direct spray | 0.00000000205 | | |
| Eating legumes—direct spray | 0.00000000410 | | |

Note: Risks are upper 95-percent confidence levels. Cancer potency value for malathion is 0.00376.

## Table B3-12. Predicted Lifetime Cancer Risk for AZINPHOS-METHYL in an Eradication Program

| Exposure scenario | Risk | | |
|---|---|---|---|
| | Realistic | Intermediate | Maximum |
| **Public:** | | | |
| Dermal and inhalation drift | 0.0000000000197 | 0.0000000000364 | 0.0000000000551 |
| Dietary— | | | |
| Water | 0.0000000000254 | 0.0000000000468 | 0.0000000000709 |
| Fish | 0.000000000254 | 0.000000000468 | 0.000000000709 |
| Venison | 0.0000000000637 | 0.000000000117 | 0.000000000178 |
| Legumes | 0.000000000854 | 0.00000000157 | 0.00000000238 |
| Berries | 0.000000000427 | 0.000000000787 | 0.00000000119 |
| **Workers:** | | | |
| Pilot | 0.000000183 | | |
| Mixer/loader | 0.000000437 | | |
| Observer | 0.00000130 | | |
| Monitoring team | 0.0000000544 | | |
| Hiboy applicator | 0.0000436 | | |
| Mist blower applicator | 0.0000194 | | |
| **Accidents:** | | | |
| Spill of concentrate | 0.00000208 | | |
| Broken hose | 0.00000208 | | |
| Immediate field entry | 0.0000000000104 | | |
| Spray at 25 feet—adult | 0.000000000153 | | |
| Direct spray—adult | 0.000000000180 | | |
| Drink reservoir water/release | 0.000000000244 | | |
| Eating berries—direct spray | 0.0000000000436 | | |
| Eating legumes—direct spray | 0.0000000000872 | | |

Note: Risks are upper 95-percent confidence levels. Cancer potency value for azinphos-methyl is 0.00039.

**Table B3-13. Predicted Lifetime Cancer Risk for DIFLUBENZURON in an Eradication Program**

| Exposure scenario | Risk | | |
|---|---|---|---|
| | Realistic | Intermediate | Maximum |
| **Public:** | | | |
| Dermal and inhalation drift | 0.000000000422 | 0.000000000777 | 0.00000000118 |
| Dietary— | | | |
| Water | 0.000000000587 | 0.00000000108 | 0.00000000164 |
| Fish | 0.0000000147 | 0.0000000270 | 0.0000000409 |
| Venison | 0.00000000143 | 0.00000000263 | 0.00000000398 |
| Legumes | 0.0000000188 | 0.0000000347 | 0.0000000525 |
| Berries | 0.00000000941 | 0.0000000173 | 0.0000000263 |
| **Workers:** | | | |
| Pilot | 0.00000118 | | |
| Mixer/loader | 0.00000279 | | |
| Observer | 0.0000127 | | |
| Monitoring team | 0.000000766 | | |
| Hiboy applicator | 0.000550 | | |
| Mist blower applicator | 0.000237 | | |
| **Accidents:** | | | |
| Spill of concentrate | 0.0000603 | | |
| Broken hose | 0.000241 | | |
| Immediate field entry | 0.000000000287 | | |
| Spray at 25 feet—adult | 0.00000000253 | | |
| Direct spray—adult | 0.00000000250 | | |
| Drink reservoir water/release | 0.00000000281 | | |
| Eating berries—direct spray | 0.000000000961 | | |
| Eating legumes—direct spray | 0.00000000192 | | |

Note: Risks are upper 95-percent confidence levels. Cancer potency value for diflubenzuron is 0.01718.

**Table B3-14. Predicted Lifetime Cancer Risk for MALATHION in a Suppression Program**

| Exposure scenario | Risk | |
|---|---|---|
| | Realistic | Maximum |
| **Public:** | | |
| Dermal and inhalation drift | 0.00000000722 | 0.0000000224 |
| Dietary— | | |
| Water | 0.0000000102 | 0.0000000318 |
| Fish | 0.000000868 | 0.00000270 |
| Venison | 0.0000000262 | 0.0000000813 |
| Legumes | 0.0000000446 | 0.000000138 |
| Berries | 0.0000000223 | 0.0000000692 |
| **Workers:** | | |
| Pilot | 0.00000456 | |
| Mixer/loader | 0.0000108 | |
| Observer | 0.0000502 | |
| Monitoring team | 0.000000210 | |
| Hiboy applicator | 0.000217 | |
| Mist blower applicator | 0.000123 | |
| **Accidents:** | | |
| Spill of concentrate | 0.0000481 | |
| Broken hose | 0.0000481 | |
| Immediate field entry | 0.0000000000516 | |
| Spray at 25 feet—adult | 0.00000000438 | |
| Direct spray—adult | 0.00000000439 | |
| Drink reservoir water/release | 0.0000000110 | |
| Eating berries—direct spray | 0.00000000205 | |
| Eating legumes—direct spray | 0.00000000410 | |

Note: Risks are upper 95-percent confidence levels. Cancer potency value for malathion is 0.00376.

**Table B3-15. Predicted Lifetime Cancer Risk for AZINPHOS-METHYL in a Suppression Program**

| Exposure scenario | Risk | |
|---|---|---|
| | Realistic | Maximum |
| **Public:** | | |
| Dermal and inhalation drift | 0.000000000175 | 0.000000000542 |
| Dietary— | | |
| Water | 0.000000000225 | 0.000000000698 |
| Fish | 0.0000000207 | 0.0000000642 |
| Venison | 0.000000000563 | 0.00000000175 |
| Legumes | 0.000000000979 | 0.00000000304 |
| Berries | 0.000000000489 | 0.00000000152 |
| **Workers:** | | |
| Pilot | 0.000000183 | |
| Mixer/loader | 0.000000437 | |
| Observer | 0.00000130 | |
| Monitoring team | 0.0000000544 | |
| Hiboy applicator | 0.0000436 | |
| Mist blower applicator | 0.0000194 | |
| **Accidents:** | | |
| Spill of concentrate | 0.00000206 | |
| Broken hose | 0.00000208 | |
| Immediate field entry | 0.0000000000104 | |
| Spray at 25 feet—adult | 0.000000000153 | |
| Direct spray—adult | 0.000000000180 | |
| Drink reservoir water/release | 0.000000000244 | |
| Eating berries—direct spray | 0.0000000000436 | |
| Eating legumes—direct spray | 0.0000000000872 | |

Note: Risks are upper 95-percent confidence levels. Cancer potency value for azinphos-methyl is 0.00039.

For the suppression program, the extreme case assumed 14 applications the first year, 22 the second year, 16 the third year, and 13 the fourth year. Assuming that the insect populations are dynamic, this pattern of applications is repeated over a period of 30 years, for a total of 522 exposures.

Cancer risks for accidents were based on a single exposure in a lifetime.

### Estimation of Cancer Risk

The estimation of cancer risk to exposed individuals is based on the following linear cancer risk estimation equation:

$$\text{risk} = 1.0 - e^{-(\text{cancer potency} \times \text{average dose})}$$

(Equation B3.20)

Cancer potency is a measure of the potential of a chemical to cause cancer in humans. The average dose (lifetime) is calculated by multiplying the number of exposures over a lifetime by the dose and then dividing by the assumed average lifetime of 70 years (25,550 days). When this equation is properly applied, an extremely small number is usually calculated. Cancer risk values greater than 0.00001 to 0.000001 are considered to be significant (EPA, 1986; ENVIRON, 1988).

As a final measure of the public cancer risk sensitivity to the National Boll Weevil Cooperative Control Program, it was assumed that malathion, which has a cancer potency of 0.02, was consumed from the source with the highest dose (legumes— 0.00075 mg/kg/day for typical scenarios and 0.0050 mg/kg/day for extreme scenarios). Assuming 90 percent typical exposure and 10 percent extreme exposure, for 25 exposures per year over a period of 20 years, the calculated cancer risk to the public by this route is $4.6 \times 10^{-7}$. Cancer risks are discussed in more detail in section B4 of this appendix.

### Time Dependence of Dermal Exposure Resulting From Vegetation Contact

Insecticide residues on plant surfaces decline over time as a result of absorption by the plant, degradation, volatilization, and being washed off by rainfall. After insecticide sprays dry on plant surfaces, they cannot be completely removed because they bind to the plant surface. As a result, persons entering a treated area a short time after spraying are likely to receive dermal doses that are much smaller than the conservative doses calculated in this analysis. However, specific data were not available about the persistence on plant surfaces of the insecticides covered. The most appropriate data would be measurements of dislodgeable residues, but these type of data were not available for the insecticides covered in this EIS. In most cases, measurements of total plant residues over time were available, so these data have been used to calculate degradation rates where surface area measurements are unavailable. Degradation rates calculated in this manner should be considered minimum degradation rates for dislodgeable residues because the residues that were measured in deriving the data may have been largely or entirely unavailable for dermal exposure through contact with vegetation.

# Section B4

# Human Health Risk Analysis

## Overview

This section analyzes the potential risks to the health of members of the public and workers from the proposed boll weevil eradication and suppression alternatives. Human health risks are analyzed by comparing estimated insecticide exposure levels (described in the exposure analysis section) to toxicity levels established in the laboratory studies (or, in the case of malathion, human studies) described in the hazard analysis section.

The first subsection describes the methodology used to evaluate human health risks, including systemic and reproductive toxicity. The second subsection describes the methodology used to evaluate cancer risks. The third subsection describes the use of mitigation measures to reduce risks. The fourth subsection evaluates the carcinogenic risks (including systemic and reproductive toxicity, as well as cancer) to the public and workers from eradication operations. The fifth subsection evaluates the carcinogenic risk for the public and workers from suppression operations. The sixth subsection presents qualitative analyses of additional risks, including mutagenic risk, synergistic effects, and cumulative effects.

## Methods for Evaluating Systemic and Reproductive Effects

Human health risks from exposure to insecticides were quantified by comparing toxicity levels established in the most sensitive laboratory animal species and humans, if available (presented in section B2 of this appendix) to estimated doses from the exposure scenarios (presented in section B3 of this appendix). Toxicity levels used in the human health risk analysis are summarized in table B4-1.

To quantify the risks of acute, chronic, and reproductive developmental health effects, estimated doses were compared to laboratory no-observed-effect levels (called NOELs). The NOEL is the highest dose producing no effect in the laboratory test species or humans. The ratio between the NOEL and the estimated human dose level is called the margin of safety (MOS): MOS = NOEL/Dose. For example, a laboratory animal NOEL of 20 milligrams per kilogram (mg/kg) divided by an estimated human dose of 0.2 mg/kg results in an MOS of 100. The MOS approach is used to compensate for the inherent uncertainty in relating dosage levels in animals to health risks in humans. For comparing estimated doses to laboratory animal NOELs, an MOS of 100 is generally recognized as safe for humans and is comparable to the 100-fold uncertainty factor that the Environmental Protection Agency (EPA) uses to establish reference doses (or acceptable intake levels) for humans. The 100-fold safety factor accounts for the extrapolation from animals to humans and for the variability within humans. The larger the MOS (the smaller the estimated human dose compared to the NOEL), the lower the risk to human health. For comparison with the NOELs based on human studies, an MOS of 10 is

**Table B4-1. Toxicity Levels Used in This Analysis**

| Insecticide | Acute oral $LD_{50}$ in rats (mg/kg) | Systemic NOEL (mg/kg/day) | | Reproductive/ developmental NOEL (mg/kg/day) | Cancer potency (mg/kg/day) |
|---|---|---|---|---|---|
| | | Human | Rat | | |
| Malathion | 370 | 0.23 | 5.0 | 25.0 | 0.00376 |
| Azinphos-methyl | 4.4 | 0.286 | 0.125[a] | 2.5 | 0.00039 |
| Diflubenzuron | >4,640 | NA | 1.0[a] | >8.0 | 0.01718 |
| Methyl parathion | 3.6 | 0.31 | 0.025 | 0.25 | — |
| Xylene (inert) | 4,300 | NA | 179.0 | 0.3 | — |

[a] This NOEL is based on a 2-year dog feeding study.

Note: NA = Not available.
— = Cancer risk assessment is not conducted for these two chemicals.

considered safe for malathion and azinphos-methyl. For methyl parathion, EPA recommends a safety factor of 100 for the human studies, so an MOS of 100 is used.

For all chemicals, systemic effects were evaluated on the basis of the lowest systemic NOEL established in 2-year feeding studies with dogs or rats. When available, systemic effects were also evaluated on the basis of studies with human volunteers. These studies were generally 4 weeks in duration (malathion study was 7 weeks/mg). Reproductive effects were evaluated for all chemicals on the basis of the lowest maternal, fetotoxic, or teratogenic NOEL found in a three-generation reproductive or teratogenic study. The reproductive NOEL for diflubenzuron is based on the highest dose tested and may overstate risks.

As the estimated dose to humans approaches the NOEL, the risk to humans increases. When an estimated dose exceeds a NOEL, the ratio is reversed (that is, the dose is divided by the NOEL) to indicate the factor by which the estimated dose exceeds the NOEL. In this case, the MOS is designated by a negative number. An MOS of –10, for example, indicates that the estimated dose is 10 times the NOEL. Estimated doses that significantly exceed the NOEL are also compared to the acute oral median lethal dose ($LD_{50}$) to determine the risk of fatalities.

Although an MOS less than 100 (or 10 in the case of some human studies) is considered to present a risk of toxic effects, it should be noted that the MOS is based on a comparison with the dose level that produced no effects in laboratory animals or humans. All of the NOELs from laboratory animal studies used in this risk analysis are based on long-term exposure. The maximum number of exposures to the public is 25 per year. Hence, because the majority of laboratory animal NOELs were established from daily exposures of up to 2 years, this comparison may tend to overestimate risks to humans. For the public, it may be more useful to compare the estimated doses to the NOELs from the human studies, as the length of exposures in these studies more closely matches possible public exposures. For accidents in particular, a one-time or once-a-year dose is compared to NOELs derived from long-term studies.

MOSs were computed for malathion, azinphos-methyl, diflubenzuron, methyl parathion, and xylene (an inert ingredient) using program application rates. Although propoxyr and chlorpyrifos may be used in traps for the boll weevil eradication or suppression programs, the potential for exposure of these insecticides to workers and the public is not considered significant. Therefore, these chemicals were not included in the risk analysis. MOSs were computed for workers and the public for typical and extreme exposures that may occur during routine insecticide application operations. In addition, MOSs were computed for exposures that may occur during accidents or pesticide spills.

In comparison with animal studies (and the human study for methyl parathion), MOSs greater than 100 represent negligible risk to human health. MOSs between 50 and 100 present a slight risk of low-level health effects, particularly for sensitive individuals. MOSs between 10 and 50 are considered to indicate a slight to moderate risk of low-level health effects, especially in light of the extrapolation from animals to humans; MOSs between 1 and 10 are considered to present a moderate to significant risk of health effects to the general public; however, for sensitive individuals, an MOS in this range may present a significant risk of health effects. Sensitive individuals may include, but are not limited to, children, the elderly, persons allergic to pesticides, or persons with an existing health condition, such as a respiratory disease. In comparison with the human studies, MOSs greater than 10 represent negligible risks to human health. MOSs between 10 and 1 indicate moderate risk, and MOSs less than 1 indicate significant risk to human health. Risks may be significant when the exposure exceeds the NOEL (as indicated by a negative MOS). In cases when the exposure significantly exceeds the NOEL (for example, in accidental exposures), the risk is quantified by computing an MOS between the exposure and the $LD_{50}$. Exposures that approach the laboratory animal $LD_{50}$ are considered to present a danger of severe adverse health effects.

## How Cancer Risks to the Public and Workers Were Determined

A cancer risk analysis was conducted for malathion and azinphos-methyl based on evidence from laboratory animal studies that suggests that these insecticides may have the potential to cause cancer. Although laboratory animal studies on diflubenzuron suggest that it may not have carcinogenic potential, EPA has calculated a cancer potency, and a cancer risk analysis was conducted for this chemical as well. A cancer risk analysis was not conducted for methyl parathion because it does not appear to be carcinogenic based on laboratory animal study data. Xylene was not included in the cancer risk analysis because there are no study data to indicate that it is carcinogenic.

The risk of cancer is calculated for an individual by multiplying estimates of lifetime dose over a 70-year period by cancer potency estimates derived in the hazard analysis (section B2 of this appendix).

The cancer risk analysis for the public and workers from the boll weevil eradication program was based on three exposure scenarios—realistic, intermediate, and maximum. The realistic case was based on the average number of applications required for boll weevil eradication. The maximum exposure scenario in the cancer risk analysis is based on the maximum estimated number of applications for a heavily infested area. This scenario assumes a significantly higher number of applications than the realistic scenario. The rationale for using the highest number of applications per year for the maximum exposure scenarios is to account for the "worst case" exposure levels, which ensures that risks will not be underestimated in the cancer risk analysis.

In addition, an intermediate exposure analysis was performed for a scenario in which the number of applications is the average of the

number in the realistic and maximum exposure scenarios. Although the intermediate exposure analysis is not based on a realistic application program in the boll weevil control program, it was included to provide a measurement of sensitivity between the cancer risk and the number of applications per year.

For boll weevil suppression program cancer risk analysis, realistic and maximum exposure scenarios were analyzed. The realistic scenario was based on the average number of treatments in a suppression program. The maximum scenario was based on a theoretical maximum number of treatments for boll weevil suppression.

Cancer risks to workers are calculated based on an estimated maximum of 30 years of employment. These risks were based on the exposures calculated for the systemic and reproductive risk analysis. Of the exposures received during the 30 years, 10 percent are assumed to be routine-extreme, and 90 percent are assumed to be routine-typical.

### Comparison of Cancer Risks With Other Common Risks

Risks associated with familiar hazards and occupational risks are presented in table B4-2 to provide a comparison for cancer risks associated with insecticide exposures. A variety of hazards have a risk of approximately 1 in 1 million, including smoking 2 cigarettes, eating 6 pounds of peanut butter, drinking 40 sodas sweetened with saccharin, or taking 1 transcontinental round trip by air. Many occupational risks are greater. For example, working for 30 years in agriculture or construction has a risk of approximately 2 in 100, while mining and quarrying have a greater risk of 3 in 100 for 30 years of exposure.

## The Use of Mitigation Measures to Reduce Risk

Several mitigation measures, including workers wearing protective clothing and working in enclosed areas (for example, a sealed cockpit), can reduce risk. This information is based on worker field studies that measure the variability of exposure when various protective measures are taken (according to a personal communication with Curt Lunchick, Office of Pesticides and Toxic Substances, EPA, 1988). Field studies have demonstrated that worker exposures can be reduced by 27 to 99 percent by the use of protective clothing. In a field study conducted by Davies et al. (1982), mixers reduced their exposure by 35 percent and sprayers reduced their exposure by 49 percent by wearing coveralls during insecticide applications to orchards.

All worker exposure estimates in this analysis are based on the assumption that workers do not wear protective clothing. Protective clothing would be assumed to decrease risk to workers by approximately one order of magnitude.

## Risks From Control Operations

This section presents the results of the risk analysis for boll weevil eradication and suppression programs. The MOSs are based on exposure methods and scenarios presented in section B3 of this appendix.

MOSs for control program operations are summarized in tables B4-3 through B4-6 for typical public, extreme public, typical worker, and

**Table B4-2. Lifetime Risk of Death or Cancer Resulting From Everyday Activities**

| Activity | Time needed to accumulate a 1 in 1 million risk of death | Average annual risk per capita |
|---|---|---|
| **Based on living in the United States:** | | |
| Motor vehicle accident | 1.5 days | 0.0002 |
| Falls | 6 days | 0.00006 |
| Drowning | 10 days | 0.00004 |
| Fires | 13 days | 0.00003 |
| Firearms | 36 days | 0.00001 |
| Electrocution | 2 months | 0.000005 |
| Tornados | 20 months | 0.0000006 |
| Floods | 20 months | 0.0000006 |
| Lightning | 2 years | 0.0000005 |
| Animal bite or sting | 4 years | 0.0000002 |
| **Occupational risks:** | | |
| General— | | |
| Manufacturing | 4.5 days | 0.00008 |
| Trade | 7 days | 0.00005 |
| Service and government | 3.5 days | 0.00001 |
| Transport and public utilities | 1 day | 0.0004 |
| Agriculture | 15 days | 0.0006 |
| Construction | 14 hours | 0.00000000000006 |
| Mining and quarrying | 9 hours | 0.006 |
| Specific— | | |
| Coal mining (accidents) | 14 hours | 0.0006 |
| Police duty | 1.5 days | 0.0002 |
| Railroad employment | 1.5 days | 0.0002 |
| Firefighting | 11 days | 0.0008 |

Table B4-3. Summary of TYPICAL EXPOSURES to the PUBLIC From the National Boll Weevil Cooperative Control Program

| Chemical | MOSs[a] for systemic effects (human NOEL) | MOSs[b] for systemic effects (rat or dog NOEL) | MOSs[b] for reproductive effects |
|---|---|---|---|
| Malathion | All MOSs greater than 10 | All MOSs greater than 100 | All MOSs greater than 100 |
| Azinphos-methyl | All MOSs greater than 10 | All MOSs greater than 100 | All MOSs greater than 100 |
| Diflubenzuron | NA | All MOSs greater than 100 | All MOSs greater than 100 |
| Methyl parathion | All MOSs greater than 100 | MOSs less than 100 for consumption of venison that received spray drift at 25 feet and consumed contaminated diet items. | All MOSs greater than 100 |
| Xylene | NA | All MOSs greater than 100 | All MOSs greater than 100 |

[a] MOSs greater than 10 (greater than 100 for methyl parathion) are considered acceptable levels of risk.
[b] MOSs greater than 100 are considered acceptable levels of risk; risks of reproductive effects from diflubenzuron may be overstated.

**Table B4-4. Summary of EXTREME EXPOSURES to the PUBLIC From the National Boll Weevil Cooperative Control Program**

| Chemical | MOSs[a] for systemic effects (human NOEL) | MOSs[b] for systemic effects (rat or dog NOEL) | MOSs[b] for reproductive effects |
|---|---|---|---|
| Malathion | MOSs less than 10 for consumption of fish from a pond that has received drift from 25 feet | MOSs less than 100 for consumption of fish from a pond that has received 25-foot drift | All MOSs greater than 100 |
| Azinphos-methyl | All MOSs greater than 10 | MOSs less than 100 for consumption of fish from a pond that has received 25-foot drift and for consumption of legumes and berries that have received drift from 25 feet | All MOSs greater than 100 |
| Diflubenzuron | NA | MOSs less than 100 for consumption of fish from a pond that has received 25-foot drift | All MOSs greater than 100 |
| Methyl parathion | MOSs less than 100 for consumption of legumes and berries that have received spray drift at 25 feet; MOSs less than 1 for consumption of fish from a pond that has received spray drift at 25 feet | MOSs less than 100 for exposure to dermal and inhalation drift at 100 feet; for consumption of venison and water that has been directly sprayed; and for consumption of legumes and berries that have received spray drift from 25 feet; MOSs less than 1 for consumption of fish from a pond that has received 25-foot drift | MOSs less than 100 for consumption of legumes and berries that have received spray drift from 25 feet; MOSs less than 1 for consumption of fish from a pond that has received 25-foot drift |
| Xylene | NA | All MOSs greater than 100 | All MOSs greater than 100 |

[a] MOSs greater than 10 (greater than 100 for methyl parathion) are considered acceptable levels of risk.
[b] MOSs greater than 100 are considered acceptable levels of risk; risk of reproductive effects from diflubenzuron may be overstated.

**Table B4-5. Summary of TYPICAL EXPOSURES to WORKERS From the National Boll Weevil Cooperative Control Program**

| Chemical | MOSs[a] for systemic effects (human NOEL) | MOSs[b] for systemic effects (rat or dog NOEL) | MOSs[b] for reproductive effects |
|---|---|---|---|
| Malathion | MOSs less than 10 for observers and hiboy and mist blower operators | MOSs less than 100 for observers and hiboy and mist blower operators | All MOSs greater than 100 |
| Azinphos-methyl | MOSs less than 10 for hiboy and mist blower operators | MOSs less than 100 for pilots, mixer/loaders, and observers; less than 1 for hiboy and mist blower operators | MOSs less than 100 for hiboy and mist blower operators |
| Diflubenzuron | NA | MOSs less than 10 for hiboy and mist blower operators | MOSs less than 100 for hiboy and mist blower operators |
| Methyl parathion | MOSs less than 100 for mixer/loader, observer, and hiboy and mist blower operators | MOSs less than 100 for pilots, mixer/loaders, and monitoring team; MOSs less than 1 for observers and hiboy and mist blower operators | MOSs less than 100 for observers, mixer/loaders, and hiboy and mist blower operators |
| Xylene | NA | All MOSs greater than 100 | MOSs less than 100 for hiboy and mist blower operators |

[a] MOSs greater than 10 (greater than 100 for methyl parathion) are considered acceptable levels of risk.
[b] MOSs greater than 100 are considered acceptable levels of risk; risk of reproductive effects from diflubenzuron may be overstated.

**Table B4-6. Summary of EXTREME EXPOSURES to WORKERS From the National Boll Weevil Cooperative Control Program**

| Chemical | MOSs[a] for systemic effects (human NOEL) | MOSs[b] for systemic effects (rat or dog NOEL) | MOSs[b] for reproductive effects |
|---|---|---|---|
| Malathion | MOSs less than 10 for mixer/loaders; MOSs less than 1 for observers and hiboy and mist blower operators | MOS less than 100 for observers and hiboy and mist blower operators | MOSs less than 100 for observers and hiboy operators |
| Azinphos-methyl | MOS less than 10 for observers; MOSs less than 1 for hiboy and mist blower operators | MOSs less than 100 for pilots and mixer/loaders; MOSs less than 1 for observers and hiboy and mist blower operators | MOSs less than 100 for observers, and hiboy and mist blower operators |
| Diflubenzuron | NA | MOSs less than 100 for observers and mist blower operators; MOSs less than 1 for hiboy operators | MOSs less than 100 for hiboy and mist blower operators |
| Methyl parathion | MOSs less than 100 for pilots, mixer/loaders, observers, and hiboy and mist blower operators | MOSs less than 100 for monitoring team, pilots, and mixer/loaders; MOSs less than 1 for observers and hiboy and mist blower operators | MOSs less than 100 for pilots and mixer/loaders; less than 1 for observers and hiboy and mist blower operators |
| Xylene | NA | All MOSs greater than 100 | MOSs less than 100 for observers and mist blower operators; MOSs less than 0 for hiboy operators |

[a] MOSs greater than 10 (greater than 100 for methyl parathion) are considered acceptable levels of risk.
[b] MOSs greater than 100 are considered acceptable levels of risk.

extreme worker exposures, respectively. Individual public, worker, and accident MOSs for azinphos-methyl, malathion, diflubenzuron, methyl parathion, and xylene are summarized in tables B4-7 through B4-11, respectively.

## Risk of Systemic and Reproductive Effects

### Risk to the Public From Routine Control Operations

***Routine-Typical Exposures.*** In comparison with toxicity levels found in human studies on malathion, MOSs for typical public exposures are greater than 10 for systemic effects, indicating that no adverse effects are expected to occur from typical malathion exposures. Similarly, all MOSs for azinphos-methyl and methyl parathion are greater than 10 and 100, respectively. No adverse systemic and reproductive effects are expected to occur.

Based on toxicity levels determined in laboratory animal studies, all MOSs for malathion are less than 100 for systemic and reproductive effects, indicating that no adverse effects are expected.

Similarly, all MOSs for routine-typical azinphos-methyl and diflubenzuron exposures exceed 100. Therefore, no adverse systemic and reproductive effects are expected to occur from routine-typical azinphos-methyl or diflubenzuron exposures.

For routine-typical methyl parathion exposures, MOSs are less than 100 for the consumption of 0.5 kg/day of venison, assuming the deer received a dermal drift dose at 25 feet and consumed forage and water receiving drift at 25 feet. This risk can be reduced if spraying when deer are present is avoided. MOSs for routine-typical exposures to xylene (an inert ingredient in the methyl parathion formulation Penncap M®) are greater than 100 for systemic and reproductive effects; thus, such effects are not expected to occur.

***Routine-Extreme Exposures.*** Based on toxicity levels found in a human study, malathion poses a moderate risk of systemic effects from consuming fish from a pond receiving drift at 25 feet. Compared to the human NOEL, all MOSs for azinphos-methyl are greater than 10, indicating that no adverse effects are expected. MOSs for methyl parathion indicate significant risks of systemic effects from consuming fish from a pond receiving drift at 25 feet and moderate risks from consuming legumes receiving drift from 25 feet and a slight risk of systemic effects from consuming berries receiving drift at 25 feet.

When compared to toxicity levels found in laboratory animal studies, MOSs for malathion indicate a slight risk of systemic effects from consuming fish from a pond receiving drift at 25 feet. No risks of reproductive effects are indicated.

MOSs for routine-extreme exposures to azinphos-methyl, based on laboratory animal NOELs, indicate slight risk of systemic effects to the public from consuming berries that have received drift at 25 feet, a

**Table B4-7. Control Program Margins of Safety for AZINPHOS-METHYL**

| Exposure scenario | Systemic | | | | Reproductive | |
|---|---|---|---|---|---|---|
| | Human | | Rat | | | |
| | Typical | Extreme | Typical | Extreme | Typical | Extreme |
| **Public:**[a] | | | | | | |
| Dermal and inhalation drift | 10,000 | 10,000 | 10,000 | 184 | 10,000 | 3,673 |
| Dietary— | | | 8,990 | | | |
| Water | 10,000 | 387 | 10,000 | 167 | 10,000 | 3,334 |
| Fish | 10,000 | 22 | 612 | 10 | 10,000 | 191 |
| Venison | 1,422 | 810 | 2,042 | 349 | 10,000 | 6,989 |
| Legumes | 10,000 | 89 | 4,083 | 38 | 10,000 | 766 |
| Berries | 10,000 | 178 | | 77 | 10,000 | 1,531 |
| **Workers:**[b] | | | | | | |
| Pilot | 165 | 76 | 71 | 33 | 1,423 | 655 |
| Mixer/loader | 74 | 18 | 32 | 11 | 639 | 216 |
| Observer | 21 | 2 | 9 | –1 | 179 | 19 |
| Monitoring team | 507 | 430 | 219 | 185 | 4,374 | 3,705 |
| Hiboy applicator | 1 | –8 | –2 | –18 | 9 | 1 |
| Mist blower applicator | 2 | –1 | –1 | –3 | 13 | 6 |
| **Accidents:** | | | | | | |
| Spill of concentrate | | –362 | | –806 | | –40 |
| Broken hose | | –362 | | –806 | | –40 |
| Immediate field entry | | 426 | | 184 | | 3,679 |
| Spray at 25 feet—adult | | 29 | | 12 | | 249 |
| Direct spray—adult | | 21 | | 9 | | 182 |
| Drink reservoir water/release | | 18 | | 8 | | 156 |
| Eating berries—direct spray | | 101 | | 44 | | 876 |
| Eating legumes—direct spray | | 51 | | 22 | | 438 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.
[b] Worker exposures: typical is based on average dose, extreme is based on upper 95-percent confidence level.

Note: Margins of safety (MOSs) greater than 10,000 are listed as 10,000. MOSs are based on a systemic NOEL of 0.31 in humans and 0.13 in rats and a reproductive NOEL of 2.5.

**Table B4-8. Control Program Margins of Safety for MALATHION**

| Exposure scenario | Systemic: Human Typical | Systemic: Human Extreme | Systemic: Rat Typical | Systemic: Rat Extreme | Reproductive Typical | Reproductive Extreme |
|---|---|---|---|---|---|---|
| **Public:**[a] | | | | | | |
| Dermal and inhalation drift | 10,000 | 79 | 10,000 | 1,712 | 10,000 | 8,566 |
| Dietary— | | | | | | |
| Water | 3,272 | 66 | 10,000 | 1,425 | 10,000 | 7,131 |
| Fish | 5,305 | 4 | 10,000 | 84 | 10,000 | 421 |
| Venison | 265 | 129 | 5,112 | 2,793 | 10,000 | 10,000 |
| Legumes | 751 | 15 | 10,000 | 327 | 10,000 | 1,638 |
| Berries | 1,503 | 30 | 10,000 | 655 | 10,000 | 3,275 |
| **Workers:**[b] | | | | | | |
| Pilot | 51 | 23 | 1,104 | 511 | 5,514 | 2,552 |
| Mixer/loader | 23 | 8 | 500 | 169 | 2,497 | 848 |
| Observer | 4 | –2 | 77 | 10 | 384 | 49 |
| Monitoring team | 1,042 | 669 | 10,000 | 10,000 | 10,000 | 10,000 |
| Hiboy applicator | 2 | –5 | 35 | 4 | 177 | 22 |
| Mist blower applicator | 2 | –1 | 40 | 20 | 201 | 100 |
| **Accidents:** | | | | | | |
| Spill of concentrate | | –1050 | | –48 | | –10 |
| Broken hose | | –1050 | | –48 | | –10 |
| Immediate field entry | | 656 | | 10,000 | | 10,000 |
| Spray at 25 feet—adult | | 8 | | 170 | | 850 |
| Direct spray—adult | | 6 | | 134 | | 673 |
| Drink reservoir water/release | | 3 | | 67 | | 336 |
| Eating berries—direct spray | | 17 | | 360 | | 1,793 |
| Eating legumes—direct spray | | 9 | | 179 | | 897 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.
[b] Worker exposures: typical is based on average dose, extreme is based on upper 95-percent confidence level.

Note: Margins of safety (MOSs) greater than 10,000 are listed as 10,000. MOSs are based on a systemic NOEL of 0.13 and a reproductive NOEL of 2.5.

**Table B4-9. Control Program Margins of Safety for DIFLUBENZURON**

| Exposure scenario | Systemic | | Reproductive | |
|---|---|---|---|---|
| | Typical | Extreme | Typical | Extreme |
| **Public:**[a] | | | | |
| Dermal and inhalation drift | 10,000 | 3,029 | 10,000 | 10,000 |
| Dietary— | | | | |
| Water | 10,000 | 2,667 | 10,000 | 10,000 |
| Fish | 10,000 | 61 | 10,000 | 488 |
| Venison | 9,615 | 5,494 | 10,000 | 10,000 |
| Legumes | 10,000 | 613 | 10,000 | 4,900 |
| Berries | 10,000 | 1,225 | 10,000 | 10,000 |
| **Workers:**[b] | | | | |
| Pilot | 1,782 | 823 | 10,000 | 6,583 |
| Mixer/loader | 804 | 272 | 6,434 | 2,179 |
| Observer | 143 | 16 | 1,146 | 125 |
| Monitoring team | 2,463 | 2,345 | 10,000 | 10,000 |
| Hiboy applicator | 6 | –1 | 46 | 6 |
| Mist blower applicator | 9 | 4 | 71 | 33 |
| **Accidents:** | | | | |
| Spill of concentrate | | –66 | | –8 |
| Broken hose | | –17 | | –2 |
| Immediate field entry | | 2,340 | | 10,000 |
| Spray at 25 feet—adult | | 265 | | 2,122 |
| Direct spray—adult | | 222 | | 1,779 |
| Drink reservoir water/release | | 239 | | 1,913 |
| Eating berries—direct spray | | 700 | | 5,600 |
| Eating legumes—direct spray | | 350 | | 2,800 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.
[b] Worker exposures: typical is based on average dose, extreme is based on upper 95-percent confidence level.

Note: Margins of safety (MOSs) greater than 10,000 are listed as 10,000. MOSs are based on a systemic NOEL of 1.00 and a reproductive NOEL of >8.0.

**Table B4-10. Control Program Margins of Safety for METHYL PARATHION**

| Exposure scenario | Systemic | | | | Reproductive | |
|---|---|---|---|---|---|---|
| | Human | | Rat | | | |
| | Typical | Extreme | Typical | Extreme | Typical | Extreme |
| **Public:**[a] | | | | | | |
| Dermal and inhalation drift | 10,000 | 244 | 10,000 | 20 | 10,000 | 197 |
| Dietary— | | | | | | |
| Water | 10,000 | 207 | 889 | 17 | 8,890 | 167 |
| Fish | 10,000 | –2 | 10,000 | –20 | 10,000 | –2 |
| Venison | 745 | 426 | 60 | 34 | 604 | 343 |
| Legumes | 2,540 | 47 | 204 | 4 | 2,042 | 38 |
| Berries | 10,000 | 95 | 408 | 8 | 4,083 | 77 |
| **Workers:**[b] | | | | | | |
| Pilot | 138 | 64 | 11 | 5 | 111 | 51 |
| Mixer/loader | 63 | 21 | 5 | 2 | 50 | 17 |
| Observer | 11 | 1 | –1 | –10 | 9 | –1 |
| Monitoring team | 1,152 | 740 | 93 | 60 | 928 | 596 |
| Hiboy applicator | 2 | 4 | –7 | –55 | 1 | –6 |
| Mist blower applicator | 2 | 1 | –5 | –11 | 2 | –1 |
| **Accidents:** | | | | | | |
| Spill of concentrate | | –204 | | –2,534 | | –253 |
| Broken hose | | –102 | | –1,267 | | –127 |
| Immediate field entry | | 726 | | 58 | | 585 |
| Spray at 25 feet—adult | | 21 | | 2 | | 17 |
| Direct spray—adult | | 17 | | 1 | | 14 |
| Drink reservoir water/release | | 39 | | 3 | | 31 |
| Eating berries—direct spray | | 54 | | 4 | | 44 |
| Eating legumes—direct spray | | 27 | | 2 | | 22 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.
[b] Worker exposures: typical is based on average dose, extreme is based on upper 95-percent confidence level.

Note: Margins of safety (MOSs) greater than 10,000 are listed as 10,000. MOSs are based on a systemic NOEL of 0.31 in humans and 0.03 in rats, and a reproductive NOEL of 0.3.

**Table B4-11. Control Program Margins of Safety for XYLENE**

| Exposure scenario | Systemic | | Reproductive | |
|---|---|---|---|---|
| | Typical | Extreme | Typical | Extreme |
| **Public:**[a] | | | | |
| Dermal and inhalation drift | 10,000 | 10,000 | 10,000 | 5,022 |
| Dietary— | | | | |
| Water | 10,000 | 10,000 | 10,000 | 8,001 |
| Fish | 10,000 | 10,000 | 10,000 | 381 |
| Venison | 10,000 | 10,000 | 10,000 | 4,121 |
| Legumes | 10,000 | 10,000 | 10,000 | 1,838 |
| Berries | 10,000 | 10,000 | 10,000 | 3,675 |
| **Workers:**[b] | | | | |
| Pilot | 10,000 | 10,000 | 1,336 | 617 |
| Mixer/loader | 10,000 | 10,000 | 603 | 204 |
| Observer | 10,000 | 10,000 | 216 | 24 |
| Monitoring team | 10,000 | 10,000 | 702 | 702 |
| Hiboy applicator | 1,036 | 130 | 2 | –5 |
| Mist blower applicator | 1,624 | 741 | 3 | 1 |
| **Accidents:** | | | | |
| Spill of concentrate | | 14 | | –42 |
| Broken hose | | 14 | | –42 |
| Immediate field entry | | 10,000 | | 702 |
| Spray at 25 feet—adult | | 10,000 | | 555 |
| Direct spray—adult | | 10,000 | | 183 |
| Drink reservoir water/release | | 10,000 | | 94 |
| Eating berries—direct spray | | 10,000 | | 525 |
| Eating legumes—direct spray | | 10,000 | | 263 |

[a] Dermal and inhalation exposures: typical at 500 feet, extreme at 100 feet; dietary exposures: typical at 100 feet, extreme at 25 feet.
[b] Worker exposures: typical is based on average dose, extreme is based on upper 95-percent confidence level.

Note: Margins of safety (MOSs) greater than 10,000 are listed as 10,000. MOSs are based on a systemic NOEL of 179.0 and a reproductive NOEL of 0.3.

moderate risk of systemic effects from consuming legumes that have received drift at 25 feet, and a significant risk of systemic effects from consuming fish that have received drift at 25 feet. No risks of reproductive effects are indicated.

The MOS for the consumption of fish from a pond that has received drift at 25 feet indicates a slight risk of systemic effects to the public from diflubenzuron. All other MOSs are greater than 100, indicating that no adverse effects are expected to occur.

For methyl parathion, routine-extreme exposures with MOSs less than 100 include dermal and inhalation drift at 100 feet; consumption of water that has received drift residues at 25 feet; and consumption of venison from a deer that has been directly sprayed, has consumed forage with drift residues at 25 feet, and consumed water from the pond. MOSs for these exposures indicate a slight to moderate risk of systemic effects. The MOSs for consumption of berries and legumes that have received drift residues at 25 feet indicate a slight to moderate risk of reproductive effects and a significant risk of systemic effects. The MOS for consuming fish from a pond that has received drift at 25 feet indicates a significant risk of systemic and reproductive effects. The MOS for systemic effects from consuming fish is -20, meaning the dose exceeds the NOEL for this chemical.

These risks can be reduced if the public is warned not to eat fish from ponds within 50 feet of treated fields and reminded to wash fruits and vegetables before consuming them. Risks from consuming venison can be reduced if spraying is avoided when deer are present.

### Risks to the Public From Accidents

Accident scenarios for the public include direct exposure of an adult to aerial spray, exposure of an adult to drift at 25 feet, consumption of legumes or berries that have been directly sprayed and consumption of water from a reservoir that has received an 80-gallon accidental spill of insecticide spray mix from an aircraft.

The severity of accidents depends on the duration of exposure and the extent of precautions taken in the event of an accident. For example, washing exposed areas of skin following dermal contact with sprayed vegetation and washing food prior to consumption significantly reduces that amount of exposure; consequently, the MOS is also substantially increased.

When calculated with toxicity levels found in human studies, the MOSs for malathion indicate moderate risks of systemic effects to the public from being directly sprayed, from spray drift at 25 feet, and from consumption of legumes and berries that have been directly sprayed. In addition, there are risks of systemic effects to the public from being directly sprayed and from consuming water from a reservoir that received an accidental spill.

The MOSs for azinphos-methyl are greater than 10, indicating that no risk of systemic or reproductive effects is expected. For methyl parathion, MOSs are less than 100 for receiving spray drift at 25 feet, receiving direct spray, drinking water that received a spill of methyl parathion, and eating berries and legumes that contain direct spray residues. Precautions to reduce risk include cessation of spraying when a person is seen within 50 feet of the treatment area and reminding the public to wash all fruits and vegetables before consuming, to not consume fruits or vegetables located within 25 feet of the spray area, and to avoid drinking water from a contaminated reservoir until monitoring data indicate that it is safe.

Based on laboratory animal toxicity data, MOSs for malathion are less than 100 for drinking water from a contaminated reservoir, indicating a slight risk of systemic effects.

MOSs for azinphos-methyl accidental exposures indicate moderate risks of systemic effects from consuming berries or legumes that have been directly sprayed and from receiving dermal and inhalation exposures at 25 feet. MOSs indicate significant risks from being directly sprayed or from consuming water from a reservoir that received an accidental spill. Precautions to reduce risk include cessation of spraying when a member of the public is seen within 50 feet of the treatment area and reminding the public to wash all fruits and vegetables before consuming them, not to consume fruits or vegetables located within 25 feet of the spray area, and to avoid drinking water from the contaminated reservoir until monitoring data indicate that it is safe.

For diflubenzuron, MOSs for accidental exposures indicate no risk of systemic or reproductive effects.

For methyl parathion, the MOSs indicate moderate risks of reproductive effects from receiving dermal and inhalation doses at 25 feet, being directly sprayed, consuming berries or legumes that received direct spray, and from consuming water from a reservoir that received an accidental spill. Significant risks of systemic effects may occur from receiving dermal and inhalation doses at 25 feet, being directly sprayed, consuming berries or legumes that received direct spray, and from consuming water from a reservoir that received an accidental spill. Mitigation measures as described above for malathion and azinphos-methyl will reduce risks for methyl parathion to acceptable levels.

MOSs for xylene indicate a slight risk to the public of reproductive effects from consuming water from a reservoir that has received an accidental spill. Water from a reservoir that has received an accidental spill of methyl parathion (and thus xylene) should not be consumed until monitoring data indicate that it is safe.

## Risks to Workers From Routine Eradication Operations

***Routine-Typical Exposures.*** Based on toxicity values found in human studies, MOSs for malathion indicate a moderate risk to observers from routine-typical exposures. For the hiboy and mist blower operators, MOSs indicate a moderate risk of systemic effects. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. For azinphos-methyl, MOSs are less than 10 for hiboy and mist blower operators, indicating risk of systemic effects. MOSs for methyl parathion indicate slight to moderate risks to mixer/loaders and observers, respectively, and significant risks to hiboy and mist blower operators. For these workers, the use of protective clothing would reduce risk to acceptable levels.

Based on toxicity levels found in laboratory animal studies, MOSs for malathion indicate moderate risks of systemic effects to observers and to hiboy and mist blower operators. No risks of reproductive effects are indicated.

MOSs for azinphos-methyl indicate a slight risk of systemic effects to pilots, and a moderate risk to mixer/loaders. Moderate to significant risks of systemic effects are indicated by the MOSs for observers. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. For pilots, a sealed cockpit during application may be substituted for protective clothing to achieve acceptable levels. The MOS is less than 1 for hiboy and mist blower operators, indicating a significant risk of systemic effects. Also, the MOS indicates a moderate to significant risk of reproductive effects to hiboy and mist blower operators. Risks to these workers can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application.

With the exception of hiboy and mist blower operators, all MOSs are greater than 100 for typical diflubenzuron exposures. MOSs indicate a slight risk of reproductive effects to mist blower operators, a slight to moderate risk of reproductive effects to hiboy operators, and moderate to significant risks of systemic effects to both hiboy and mist blower operators. Reproductive risks may be overstated; however, the reproductive NOEL for diflubenzuron was the highest dose tested. Risks to these workers can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application.

All workers using methyl parathion have MOSs of less than 100. MOSs for routine-typical exposures indicate a slight risk of systemic effects to the monitoring team. MOSs for pilots indicate a moderate to significant risk of systemic effects. MOSs for typical exposures to mixer/loaders indicate a slight to moderate risk of reproductive effects, and moderate to significant risks of systemic effects. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. For pilots, a sealed cockpit during application may be

substituted for protective clothing to achieve acceptable levels. MOSs indicate significant risks of both reproductive and systemic effects and moderate to significant reproductive effects to observers. The use of protective clothing would reduce the risk to observers to acceptable levels. MOSs for hiboy and mist blower operators indicate significant risks of both reproductive and systemic effects. Risks to these workers can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application.

Routine-typical worker exposures to xylene exhibit MOSs greater than 100 in all cases, except for hiboy and mist blower operators. For these workers, MOSs indicate a moderate to significant risk of reproductive effects to mist blower and hiboy operators. Risks to these workers can be reduced to acceptable levels by following the same procedures suggested to reduce the risks of methyl parathion.

***Routine-Extreme Exposures.*** Only 5 percent of the worker exposures are considered to be routine-extreme. The mitigation measures outlined in this analysis that are necessary for acceptable levels of risk (that is, exposures that yield MOSs greater than 100) are for these 5 percent of workers.

For malathion, all MOSs for workers based on human studies are below 10, with the exception of the pilot and the monitoring team. MOSs for mixer/loaders indicate a moderate risk of systemic effects. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. MOSs indicate a significant risk of systemic effects for observers and hiboy and mist blower operators. Risks to observers can be reduced to acceptable levels by wearing protective clothing. Risks to hiboy and mist blower operators can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application.

Azinphos-methyl MOSs based on human studies indicate moderate risks to observers and significant risks to hiboy and mist blower operators. Risks to these workers can be reduced by following the same mitigation measures proposed for malathion. MOSs for methyl parathion are less than 100 for pilots and mixer/loaders, signifying moderate risk of systemic effects, respectively. MOSs for observers and for hiboy and mist blower operators are less than 10, indicating a moderate to significant risk of systemic effects.

MOSs based on laboratory animal studies indicate that malathion poses a moderate risk to observers and mist blower operators, and a significant risk of systemic effects to hiboy operators. MOSs indicate moderate risk of reproductive effects to observers and hiboy operators.

All worker risks are below 100 for routine-extreme azinphos-methyl exposures, with the exception of the monitoring team. MOSs for pilots and mixer/loaders indicate a moderate risk of systemic effects. The MOSs for observers indicate a moderate risk of reproductive effects and

a significant risk of systemic effects. For these workers, the use of protective clothing would reduce the risk to acceptable levels. For pilots, a sealed cockpit during application may be substituted for protective clothing to achieve acceptable levels. The MOSs for hiboy and mist blower operators indicate a moderate to significant risk of reproductive effects, and a significant risk of systemic effects. Risks to hiboy and mist blower operators can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application.

For diflubenzuron, all MOSs for routine-extreme exposures are greater than 100, with the exception of observers and hiboy and mist blower operators. The MOS for observers indicates moderate risk of systemic effects. The use of protective clothing would reduce the risk to observers to acceptable levels. MOSs for mist blower operators indicate a moderate risk of reproductive effects and a significant risk of systemic effects. MOSs for hiboy operators indicate a moderate to significant risk of reproductive effects and a significant risk of systemic effects. Again, the reproductive risks from exposure to diflubenzuron may be overstated. Risks to these workers can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application.

For routine-extreme exposures to methyl parathion, all MOSs for workers are less than 100. The MOS for the monitoring team indicates a slight risk of systemic effects. MOSs for pilots indicate a slight risk of reproductive effects and a significant risk of systemic effects. MOSs for mixer/loaders indicate a moderate risk of reproductive effects and a significant risk of systemic effects. For these workers, the use of protective clothing would significantly reduce the risk to acceptable levels. For pilots, a sealed cockpit during application may be substituted for protective clothing to achieve acceptable levels. The MOSs for observers indicate a significant risk for both reproductive and systemic risks. Risks to observers can be reduced to acceptable levels by operating in an enclosed vehicle or other structure and wearing protective clothing during application procedures. The MOSs for hiboy operators and mist blower operators indicate a significant risk for both reproductive and systemic risks. For the hiboy operator, the MOS is significantly less than 1 and is approximately 50 percent of the laboratory animal $LD_{50}$; therefore, exposure to the hiboy operator could present a danger of severe adverse health effects. Risks to mist blower operators can be reduced to acceptable levels by operating in an enclosed cab and wearing protective clothing during application procedures. Additional precautions, such as using extreme caution when leaving the cab following spraying operations, must also be followed to reduce the risks to hiboy operators.

Routine-extreme worker exposures for xylene exhibit MOSs greater than 100 for all workers except observers, hiboy operators, and mist blower operators. For observers, the MOS indicates a slight to moderate risk of reproductive effects. For the mist blower operator, the

MOS indicates a moderate to significant risk of reproductive effects. For the hiboy operator, the MOS indicates a significant risk of reproductive effects. Protective measures prescribed for methyl parathion will also reduce the risks from xylene.

**Risks to Workers From Accidents**

Accidental scenarios for workers include dermal exposure from a spill of insecticide concentrate and dermal exposure from spray from a broken hose while loading the aircraft.

Dermal doses estimated in this analysis tend to exaggerate the actual dose because the dermal penetration rates used in the analysis do not incorporate a time element. In reality, the penetration rates involve a significant time factor because they were derived from studies in laboratory animals over a period of one to several days. Thus, to receive doses as high as predicted in these accidents, workers would have to ignore safety measures and not wash off the chemical following dermal contact.

Based on toxicity levels found in human studies, for malathion MOSs for workers for an accidental spill of the concentrate and for the spray from a broken hose indicate a danger of severe adverse effects. The use of protective clothing and immediate washing of the skin following an accident would significantly reduce the risk of adverse health effects.

Azinphos-methyl MOSs based on human studies indicate severe risks of systemic effects from a spill of concentrate and a broken hose. Accident MOSs for methyl parathion indicate severe risks of systemic effects from an accidental spill of the concentrate and for spray from a broken hose. Following the procedures used for malathion would significantly reduce the risk of adverse health effects of these two chemicals.

MOSs based on laboratory animal studies for malathion indicate significant risks from a spill of concentrate and a broken hose. The use of protective clothing and immediate washing of the skin following an accident would significantly reduce adverse health effects.

For azinphos-methyl, MOSs for an accidental spill of concentrate and for spray from a broken hose indicate a danger for severe adverse effects. The dose received from these accidents is over 2 times greater than the laboratory animal $LD_{50}$; therefore, fatalities may potentially occur. As in the case of malathion, washing immediately after contact and wearing protective clothing would significantly reduce the risk of adverse health effects. Available equipment necessary for immediate washing procedures would enhance the effectiveness of this emergency procedure and further reduce risk.

MOSs for work accidents involving diflubenzuron indicate significant to severe risks of systemic and reproductive health effects. Washing

immediately after contact and wearing protective clothing would significantly reduce the risk of adverse health effects.

For methyl parathion, MOSs for an accidental spill and a broken hose indicate a severe danger of adverse effects. The dose received in the event of an accidental spill is 18 times greater than the $LD_{50}$. The dose received in the event of a spray with a broken hose is nine times greater than the $LD_{50}$. Based on the comparisons with laboratory animal $LD_{50}$s, there is potential for fatalities. The use of protective clothing and washing immediately following exposure would significantly reduce the risk of adverse systemic and reproductive effects.

MOSs for accidental exposures with xylene indicate a moderate risk of systemic effects and a significant risk of reproductive effects. The precautionary measures previously discussed for methyl parathion also significantly reduce the risk of adverse health effects for xylene exposure because xylene is contained in the methyl parathion formulation.

## Cancer Risks

### Cancer Risk Scenarios for the Public and Workers

#### Cancer Risks From Eradication Operations

Cancer risks for both the public and workers are calculated for malathion, azinphos-methyl, and diflubenzuron. Methyl parathion and xylene were not included in the cancer risk analysis. Cancer risks from eradication operations are summarized in table B4-12. Cancer risks from suppression operations are summarized in table B4-13. Carcinogenic (cancer) risk to the general public in the eradication program is calculated for one realistic, one intermediate, and one maximum exposure scenario. The realistic case for eradication is based on 19 exposures over a 5-year interval, with 4, 8, 4, 2, and 1 application(s) occurring in years 1 through 5, respectively. Ninety percent of these exposures are assumed to occur under typical conditions (that is, at 500 feet for inhalation and dermal exposure and at 100 feet for all other exposures), with the remaining 10 percent occurring under extreme conditions (that is, at 100 feet for inhalation and dermal exposure and at 25 feet for all other exposures). For the intermediate exposure scenario, 35 applications are assumed to occur in 6 years with 5, 16, 8, 4, 1, and 1 application(s) per year during years 1 through 6, respectively. As for the typical scenario, 90 percent of the exposures are assumed to occur under typical conditions and 10 percent are assumed to occur under extreme conditions. In the maximum exposure scenario, 53 applications occur over a 7-year period, with the number of applications being 5, 25, 12, 6, 3, 1, and 1 during years 1 through 7, respectively. Individual exposure routes were considered separately in estimating cumulative risk.

Cancer risk to workers is calculated for 30 years of employment. Of the exposures, 10 percent are assumed to be extreme and 90 percent are assumed to be typical.

**Table B4-12. Summary of Carcinogenic Risks From Eradication**

| Chemical | Public risks | Worker risks |
|---|---|---|
| Malathion | Less than 1 in 1 million for all exposures | Greater than 1 in 1 million for pilots (5 in 1 million), mixer/loaders (1 in 100,000), observers (5 in 100,000), hiboy operators (2 in 10,000), and mist blower operators (1 in 10,000) |
| Azinphos-methyl | Less than 1 in 1 million for all exposures | Greater than 1 in 1 million for mixer/loaders (3 in 1 million), observers (1 in 100,000), hiboy operators (4 in 100,000), and mist blower operators (2 in 100,000) |
| Diflubenzuron | Less than 1 in 1 million for all exposures | Greater than 1 in 1 million for pilots (1.3 in 1 million), mixer/loaders (3 in 1 million), observers (1 in 100,000), hiboy operators (5 in 10,000), and mist blower operators (2 in 10,000) |
| Methyl parathion | EPA Group D insufficient data | EPA Group D insufficient data |

**Table B4-13. Summary of Carcinogenic Risks From Suppression**

| Chemical | Public risks | Worker risks |
|---|---|---|
| Malathion | Less than 1 in 1 million for all realistic exposures; 3 in 1 million for maximum potential consumption of fish from contaminated pond | Greater than 1 in 1 million for pilots (5 in 1 million), mixer/loaders (1 in 100,000), observers (5 in 100,000), hiboy operators (2 in 10,000), and mist blower operators (1 in 10,000) |
| Azinphos-methyl | Less than 1 in 1 million for all exposures | Greater than 1 in 1 million for mixer/loaders (3 in 1 million), hiboy operators (4 in 100,000), and mist blower operators (2 in 100,000) |
| Diflubenzuron | Not used in suppression | Not used in suppression |
| Methyl parathion | EPA Group D insufficient data | EPA Group D insufficient data |

### Cancer Risks to the Public

Cancer risks to the public are less than 1 in 1 million for all exposures from malathion, azinphos-methyl, and diflubenzuron under typical and extreme scenarios. Therefore, negligible cancer risks are expected to result from public exposures to pesticides at eradication rates.

### Cancer Risks to the Public From Accidents

For accidents, cancer risks to the public are less than 1 in 1 million for malathion, azinphos-methyl, and diflubenzuron.

### Cancer Risks to Workers

For malathion, the cancer risk to pilots is approximately 5 in 1 million. For observers, the cancer risk is approximately 5 in 100,000. For mixer/loaders, the risk is approximately 1 in 100,000. For hiboy operators and mist blower operators, the risks are 2 in 10,000, and 1 in 10,000, respectively. Precautions prescribed to reduce systemic effects will also reduce cancer risks.

Cancer risks to workers from azinphos-methyl in eradication operations are less than 1 in 1 million for all workers except observers, hiboy operators, and mist blower operators. Observers have cancer risks of approximately 1.3 in 1 million. This risk is not considered unacceptable; however, wearing protective clothing would reduce this risk to levels less than 1 in 1 million. Hiboy and mist blower operators have risks of 4 in 100,00, and 2 in 100,000, respectively. Protective clothing or operating in an enclosed cab would reduce these risks to less than 1 in 1 million.

For diflubenzuron, carcinogenic risks to pilots and mixer/loaders are approximately 1.2 and 3 in 1 million, respectively. These risks are not considered unacceptable and can be reduced to less than 1 in 1 million by wearing protective clothing. Cancer risks to observers are 1 in 100,000; protective clothing can reduce this risk to less than 100 in 1 million. Cancer risks to hiboy operators and mist blower operators are 5 in 10,000 and 2 in 10,000, respectively. Protective clothing or operating in an enclosed cab would reduce these risks to less than 1 in 1 million.

### Cancer Risks From Worker Accidents

Cancer risk from worker accidents from malathion are approximately 5 in 100,000 from a spill or a broken hose. These risks would be reduced to greater than 1 in 1 million by wearing protective clothing and washing immediately following accidental exposure.

Cancer risks for azinphos-methyl are 2 in 1 million for an accidental spill and for spray from a broken hose. Although these risks are not

considered unacceptable, the risk would be significantly reduced by washing following the accident and by wearing protective clothing.

Cancer risks for worker accidents with diflubenzuron are approximately 6 in 100,00 for an accidental spill and 2 in 10,000 for spray from a broken hose. These risks may be reduced to less than 1 in 1 million by washing immediately following an accidental exposure, and by wearing protective clothing.

## Cancer Risks From Suppression Operations

Risks of systemic and/or reproductive health effects from suppression operations are assumed to be equivalent to risks from exposure in the eradication operation because rates of application are the same in both operations. Additionally, risks of systemic and/or reproductive health effects were calculated based on doses from a single exposure. Conversely, carcinogenic risks are calculated based on a lifetime dose; therefore, the cancer risk analysis incorporates the number of lifetime exposures. Because the suppression and eradication programs differ in the number of total applications (as detailed in the subsequent discussion), carcinogenic risk from suppression operations were calculated separately.

Cancer risks from suppression operations are summarized in table B4-13. Cancer risks for malathion and azinphos-methyl operations are summarized in section B5. (Diflubenzuron would not be used in a suppression program.)

Cancer risks for the public under suppression operations were calculated based on realistic and extreme scenarios. The realistic scenario was based on 5, 7, 5, 4, and 7 applications repeated over a 30-year interval, with 90 percent of the exposures under typical conditions and 10 percent under extreme conditions. The maximum exposure scenario was based on 14, 22, 16, 13, and 22 applications for years 1, 2, 3, 4, and 5 repeated over a 30-year interval. Thus, the cycle is repeated 6 times in 30 years. The extreme scenario accounts for 522 applications in 30 years, with 90 percent of the exposures under typical conditions and 10 percent under extreme conditions.

Cancer risk for workers is calculated for 30 years of employment. Of the exposures, 10 percent are assumed to be typical.

### Cancer Risks to the Public

Cancer risks to the public under the realistic scenario are less than 1 in 1 million for all exposures to malathion and azinphos-methyl. Cancer risks to the public under the extreme scenario for malathion are 3 in 1 million for eating fish. This risk, though not considered unacceptable, may be reduced by warning the public not to consume fish from ponds within 100 feet of the treatment area.

Cancer risks to the public from accidents are less than 1 in 1 million for all exposures to malathion and azinphos-methyl.

## Qualitative Discussion of Additional Risks

### Risk of Mutagenic Effects

No human studies are available that associate the insecticides in this analysis with heritable mutations. Furthermore, no risk assessments that quantify the probability of mutations from the insecticides are available in the literature or from EPA. Laboratory studies constitute the best available information on mutagenic potential. Results of the mutagenicity assays conducted on the four insecticides and xylene (an inert ingredient) are summarized in section B2, Human Health Hazard Analysis.

For certain insecticides, available mutagenicity test data are insufficient to conclude whether the chemical is a mutagen. For these insecticides, a worst case assumption is made that these insecticides have the potential to cause mutations in humans. In these cases, the results of carcinogenicity tests (section B2) or cancer risk assessments can be used to estimate the worst case risk for mutagenicity. The rationale for this assumption is summarized as follows (USDA, 1985):

> Since mutagenicity and carcinogenicity both follow similar mechanistic steps (at least those that involve genetic toxicity), the calculated risk of cancer can be used as a worst case approximation of somatic cell mutation risk. The basis for this assumption is that both mutagenicity and at least primary carcinogens react with DNA to form a mutation or DNA lesion affecting a particular gene or set of genes. The genetic lesions then require specific metabolic processes to occur, or the cells must divide to insert the lesion into the genetic code of the cell.

The cancer risk provides a worst case approximation to heritable mutations for the following reasons:

- All chemicals known to induce heritable germ cell mutation in mammals also produce cancer in mammals, and almost always at a lower total dose.

- Many chemicals that are carcinogens in rodents fail to induce heritable germ cell mutations even at the maximum tolerated dose.

- Mammalian meiotic processes in gonadal tissue appear to be much more efficient in eliminating deoxyribonucleic acid (DNA) lesions than somatic cells.

- Human epidemiology studies of populations exposed to genotoxic carcinogens (radiation exposures in Nagasaki and Hiroshima) have demonstrated significant induction of cancer but no evidence of heritable mutations.

Available data on malathion indicate that malathion does not induce gene mutations. EPA (1988a) has requested further studies to determine the mutagenic potential of malathion. For this analysis, the worst case assumption is made that malathion is a mutagen for humans. In

addition, the worst case assumption is made that the risk of heritable mutations from malathion is no greater than the cancer risk calculated in this risk analysis.

Because azinphos-methyl has tested positive in studies for gene mutation, chromosomal effects, and unscheduled DNA synthesis, the assumption was made in this risk analysis that azinphos-methyl is mutagenic. The risk of heritable mutations from azinphos-methyl is assumed to be no greater than the carcinogenic risk calculated in this risk analysis.

Diflubenzuron has tested positive for direct DNA damage and weakly positive for mitotic recombination; however, it has also tested negative in several studies for gene mutation, chromosomal effects, and DNA repair and recombination. Because the majority of mutagenic assays has revealed negative results, diflubenzuron is considered to be nonmutagenic.

Methyl parathion is considered to be mutagenic by EPA (1988b). Although methyl parathion is assumed to be mutagenic in this risk analysis, the probability of causing heritable mutations is considered to be low because methyl parathion has not demonstrated the ability to cause cancer in mammals.

Available evidence from mutagenicity data on xylene indicates that it is not mutagenic; therefore, xylene is assumed to be nonmutagenic in this analysis.

**Synergistic Effects**

Synergism occurs when the combined effect of two chemicals is greater than the sum of the individual effects of each insecticide. Because of the widespread use of agricultural chemicals in cotton-producing areas, there is potential for synergism between chemicals applied for other purposes (for example, by individuals or for other programs) and chemicals applied for the boll weevil control program.

Malathion has been identified as synergistic with numerous other chemicals in laboratory animal studies (discussed in section B2). Of the known agricultural chemicals that interact synergistically with malathion, carbaryl, disulfoton, EPN (phosphonothioic acid), parathion, and trichlorfon are used for cotton pest control. Consequently, there is a risk of synergistic effects associated with the use of malathion. These risks could be substantially reduced with increased control on the quantity and specific types of agricultural chemicals that are used concurrently.

A risk of synergistic effects is also associated with the use of azinphos-methyl. Trichlorfon, a cotton insecticide, has demonstrated synergistic activity with azinphos-methyl (Berisford et al., 1985). In addition, mixtures of azinphos-methyl with synthetic pyrethroids are synergistic (NLM, 1988). Pyrethroids used in cotton pest control include cypermethrin, fenvalerate, flucythrinate, permethrin, and tralomethrin.

Although diflubenzuron is synergistic with the defoliant DEF (commonly used on cotton crops), synergism is unlikely to occur in the treatment of cotton crops because cotton is defoliated at the end of the season, and diflubenzuron is used only for spring treatments.

Synergistic effects have been demonstrated with toxaphene and methyl parathion (Auwater, 1977); however, this chemical is no longer sold in the United States.

# Section B5

## Nontarget Species Hazard Analysis

This section reviews the toxicological information used to determine the potential hazard to nontarget wildlife organisms from the four insecticides—malathion, azinphos-methyl, diflubenzuron, and methyl parathion—considered in the program. The results of laboratory and field studies are presented on each insecticide's toxicity to mammals, birds, insects, plants, fish, aquatic invertebrates, aquatic plants, reptiles, and amphibians.

Acute toxicity studies are used to determine a number of toxic endpoints. An important endpoint is the median lethal dose ($LD_{50}$)—the dose, usually administered orally, that kills 50 percent of the test animals. In addition to acute testing, subacute laboratory feeding studies are also conducted with birds. These tests determine the median lethal concentration in the diet (dietary $LC_{50}$) that will kill 50 percent of the test birds and thus serve as indicators of a species vulnerability to contaminated diet. Another endpoint, used in aquatic toxicology, is the median lethal concentration ($LC_{50}$)—the concentration of a toxicant in the water that kills 50 percent of the test organisms within a specified time. A third endpoint is the median effective concentration ($EC_{50}$)—the concentration of a toxicant that produces a specific effect on 50 percent of the test organisms; it is often used with animals for which determining death is difficult, such as *Daphnia* sp. Whenever possible, acute $LD_{50}$ values are given at the beginning of each nontarget group's subsection.

## Malathion

### Mammalian Toxicity

Malathion is moderately toxic to mammals. The lowest oral $LD_{50}$ value for rats is 1,375 milligrams per kilogram (mg/kg) (Gaines, 1960; as cited in Dobroski and Lambert, 1984). The lowest oral $LD_{50}$s for cattle, rabbits, and mice are 53, 250, and 507 mg/kg, respectively (NIOSH, 1987).

No effects on wildlife were observed in population censuses, carcass counts, or tissue residue analyses in areas sprayed at 0.425 pounds of active ingredient per acre (lb a.i./acre) of malathion (McEwen et al., 1972; as cited in Dobroski and Lambert, 1984).

### Avian Toxicity

The oral $LD_{50}$ of malathion in chickens ranges from 150 to 850 mg/kg (EPA, 1975). It is 167 and 403 mg/kg for pheasants and horned larks, respectively (Hudson et al., 1984). The $LD_{50}$ for the mallard is 1,485 mg/kg (Smith, 1987).

The dietary $LC_{50}$ for the Japanese quail (coturnix) is 2,968 parts per million (ppm) (Hill and Camardese, 1986). The dietary $LC_{50}$s for the ring-necked pheasant, the northern bobwhite, and the mallard are

2,639, 3,497, and greater than 5,000 ppm, respectively (Hill et al., 1975; as cited in Smith, 1987). In one study, at lethal and near-lethal doses, signs of toxicity included ataxia, walking high on toes, imbalance, hypoactivity, wing-droop weakness, slowness, sitting, ptosis, falling with wings spread, tenesmus, salivation, tremors, dyspnea, and convulsions (Hudson et al., 1984). A study in Michigan found no significant adverse effects on birds and mammals in areas sprayed with malathion at 1 lb a.i./acre. Caged pheasants in the area showed no adverse effects, and no effects were observed in necropsied birds (DOI, 1963). In Texas, cotton fields were repeatedly treated with malathion at 0.75 lb to 1 lb a.i./acre. No effects on birds were noted in wildlife areas next to the fields. Caged quail placed among treated rows of cotton also showed no effects (Sinclair, 1968).

A number of other studies showed effects on bird cholinesterase (ChE) levels and some behavioral changes. Areas in Nebraska treated with 0.5 lb a.i./acre of malathion showed no significant effects on birds or mammals. However, caged domestic turkeys in treated areas that were allowed to feed on insects from those areas had slightly depressed plasma ChE levels, but no external symptoms were noted (USDA, 1985).

Birds in a forested watershed that had been treated with 0.7 lb a.i./acre of malathion seemed noticeably quiet for 2 days after the spraying. This may have been the result of acetylcholinesterase (AChE) inhibition, which has been directly related to decreased physical activity. No other effects were observed (Dobroski and Lambert, 1984).

Extremely high doses of malathion inhibit brain AChE activity in quail (Meydani and Post, 1979; as cited in Dobroski and Lambert, 1984) and ChE activity in mallard embryos (Hoffman and Eastin, 1981; as cited in Dobroski and Lambert, 1984). In a study of brain ChE activity in sparrows, a city-wide aerial application of malathion (0.2 lb a.i./acre) reduced ChE levels by 6 to 12 percent (Kucera, 1987). Although malathion reduces brain ChE and AChE levels in birds, the minimum application rate that produces this effect has not yet been determined. The Fish and Wildlife Service (1986) has suggested further research in this area.

Reproductive effects of malathion have been studied in chickens. In one study, birds were exposed to increasing amounts of malathion in their feed for 29 weeks. Doses were 220.5 mg/kg of feed for 4 weeks, 440.9 mg/kg of feed for 3 weeks, and 1,102.3 mg/kg of feed for 22 weeks. The results indicated reduced weight gains and a 25-percent mortality of the treated birds. Egg production was not affected (EPA, 1975). In another study of chickens, no reduction in the number of eggs hatched was observed after 2 years of exposure to 438 mg/kg (2,500 ppm) of malathion in feed (EPA, 1975). In a third study, eggs injected with 2.5 mg each of malathion and carbaryl did not hatch (Ghassemi et al., 1981). Other studies have confirmed that fewer chicken eggs hatch after being injected with malathion (NRC, 1977).

## Invertebrate Toxicity

### Honey Bees

The 48-hour $LD_{50}$ in honey bees (*Apis mellifera* L.) is 0.000709 mg per bee for exposure to malathion dust (Atkins et al., 1973). Malathion is highly toxic to bees and can kill them if they are present at the time of treatment. Damage to bee populations can be considerably reduced by timing the application to avoid exposing bees to freshly applied malathion.

Daytime treatments of malathion applied to an area of blooming crops or adjacent, nontarget flowering plants are usually the most hazardous to bee colonies because foraging bees are directly exposed to malathion toxicity. Additional losses may occur if daytime applications of malathion are conducted in hot temperatures, when bees often cluster outside the hive. Therefore, night and early morning applications of malathion, carefully timed to avoid the bees' peak foraging hours, are considered safest (Atkins et al., 1975, 1977; as cited in Dobroski and Lambert, 1984). Also, if alternative sources of blooming plants are nearby, bee colonies one-quarter of a mile or more from the treatment site are not significantly injured. The timing of malathion treatment becomes less important with increasing distances between bee colonies and treated areas (Atkins et al., 1975, 1977; as cited in Dobroski and Lambert, 1984).

Although bees foraging for pollen are at significant risk from direct malathion treatments (Meyland and Burkhardt, 1970; as cited in Dobroski and Lambert, 1984), less mobile, hive-sheltered bees may also be threatened by contaminated pollen (Johansen and Brown, 1972; Meyland and Burkhardt, 1970; Moffett et al., 1970; all as cited in Dobroski and Lambert, 1984). Older bees (the worker bees) are generally less susceptible to insecticide toxicity than younger bees and may transport tainted pollen to the hive before dying of malathion intoxication (Meyland and Burkhardt, 1970; as cited in Dobroski and Lambert, 1984). Stored in the hive, contaminated pollen is potentially hazardous for months after the initial malathion application (Johansen and Brown, 1972; Moffett et al., 1970; all as cited in Dobroski and Lambert, 1984). Reproductive bees and the young are thus subject to long-term malathion exposure, and the damage to a colony may be severe (Johansen and Brown, 1972; Meyland and Burkhardt, 1970; Strang et al., 1968; all as cited in Dobroski and Lambert, 1984). However, protective steps, such as moving a colony away from a designated treatment site for 3 days or more or confining the bees during and after spraying, will prevent significant mortality (Atkins et al., 1977, 1975b; Agricultural Research Service, 1977, 1972, 1967; all as cited in Dobroski and Lambert, 1984).

Ultra-low-volume (ULV) application of malathion extends its residual life and, compared to the dilute treatments, increases its toxicity to bees by a factor of four (Levin et al., 1968; Johansen, 1979; all as cited in Dobroski and Lambert, 1984). Also, aerial application of pesticides has been shown to be more hazardous to bees than ground-based

treatments, and granular applications have been determined safest for bees, according to sources cited in Dobroski and Lambert (1984).

### Other Invertebrates

As a broad-spectrum pesticide, malathion is toxic to both the target pests and to beneficial insects on the same plant. However, there is frequently a substantial difference between these groups in their susceptibility to malathion (Abdelrahman, 1973; Cohen et al., 1987).

Malathion is toxic to beneficial parasites and predators, such as ladybird beetles (ladybugs) and parasitic wasps. A study of predaceous insect populations was conducted over 2 years during which repeated applications of 0.35 and 0.70 lb/acre a.i. malathion were made annually. The applications reduced the field populations approximately 1 month earlier than in the control fields for all the predators monitored—ladybugs, scymnus beetles, minute pirate bugs, big-eyed bugs, lacewings, and spiders. However, researchers found that the only significant decrease in the populations of predators the following spring was for nonflying predators, the spiders, which would not be able to emigrate back to the treated fields as rapidly (Laster and Brazzel, 1968).

Research shows that certain insect families and orders are more susceptible to malathion application than others. This may be because of a protective cover over the insect, as with scale insects (Cohen et al., 1987), differences in behavior patterns (Abu and Ellis, 1977), or innate metabolic causes (Abdelrahman, 1973).

In California citrus groves that were sprayed with a variety of pesticides over several years, naturally occurring populations of *Aphytis melinus*, a parasitoid of the California red scale, exhibited resistance to various pesticides, including malathion. The most resistant of these populations was more than 500 percent more resistant to malathion than was a long-term laboratory culture that had not been exposed to pesticides (Rosenheim and Hoy, 1986). A comparable degree of resistance to malathion has been reported for predaceous green lacewings from apple orchards treated with organophosphates (Pree et al., 1989). These studies reveal that some beneficial insects survive pesticide applications and may develop resistance to malathion, enabling them to continue in their role of controlling pest insects after malathion applications.

Reductions of beneficial insects are only temporary because these insects reestablish through immigration. Moreover, some species have genes for resistance or are in a protected location or life stage during insecticide application (Lingren et al., 1972; Washburn et al., 1983).

## Plant Toxicity

The available evidence suggests that malathion is generally nontoxic to plants. The insecticide is registered for use on many different fruit trees, ornamental plants, vegetation, and field crops, including corn, wheat, and cotton (American Cyanamid Company, 1987). However,

injury from malathion has been reported on apples, sweet cherries, pears, cucurbits, string beans, and certain ornamentals, including ferns, hickory, viburnum, lantana, Crassula and Canaerti junipers, petunia, spirea, white pines, maples, and elms (Thomson, 1989). However, no information was given on either the formulation of malathion that caused the damage or the extent of the damage. Because malathion is highly toxic to honey bees and other pollinators, it may inhibit plant reproduction by killing the pollinators on which many plants depend.

A forested watershed received several sprayings of malathion at 0.72 lb a.i./acre, and no phytotoxicity was observed (Giles, 1970; as cited in Dobroski and Lambert, 1984).

## Aquatic Species Toxicity

The acute toxicity of malathion to fish, aquatic invertebrates, and the aquatic stages of amphibians, as indicated by 96-hour $LC_{50}$ values, is shown in table B5-1. Technical grade malathion is the active ingredient as it is manufactured.

### Fish

The toxicity of malathion to fish depends on species, water quality, temperature, and exposure time (EPA, 1975). In general, malathion seems to be moderately to highly toxic to some species of fish. Species such as carp may tolerate this insecticide at the normal rate of application in mosquito control. Others, such as striped bass and mosquito fish, may suffer moderate to high mortality. The lowest 96-hour $LC_{50}$ found in the literature is 20 parts per billion (ppb) for the bluegill (Mayer and Ellersieck, 1986).

Malathion applied for grasshopper control in Montana slightly reduced brain ChE levels between prespray and postspray samples of cutthroat and eastern brook trout. No effect was observed on the live caged fish as a result of the 0.5 lb a.i./acre application (DOI, 1967).

Two farm ponds repeatedly treated with 1 lb a.i./acre of malathion were studied in a cotton-growing area of Texas. No mortality was reported for resident largemouth bass and other game fish and forage species (Fischer, 1966).

A study in Dawson County, Nebraska, determined that mortality rates for populations of native fish and captive bluegill (*Lepomis macrochirus*) were not directly affected by the application of ULV (227 fluid grams/acre (0.5 lb a.i./acre)) malathion (Stucky, 1976; as cited in Dobroski and Lambert, 1984). However, in a study of the relative susceptibilities of the families Ictaluridae (catfish), Cyprinidae (minnows), Centrarchidae (sunfish and bass), Percidae (perch), and Salmonidae (salmon, trout and chars) to malathion, representative species of Ictaluridae and Cyprinidae were found to have considerably more tolerance to the insecticide than Centrarchidae, Percidae, or Salmonidae (Macek and McAllister, 1970; as cited in Dobroski and Lambert, 1984).

**Table B5-1. Acute Toxicity of 95 Percent Technical Grade MALATHION to Aquatic Organisms**

| Organism | Stage or weight (g) | Water temperature (°C) | 96-hour $LC_{50}$ (mg/L) |
|---|---|---|---|
| **Fish:** | | | |
| Channel catfish (*Ictalurus punctatus*) | 1.5 | 18 | 8.970 |
| Black bullhead (*Ictalurus melas*) | 1.2 | 18 | 11.700 |
| Fathead minnow (*Pimephales promelas*) | 0.9 | 18 | 8.650 |
| Carp (*Cyprinus carpio*) | 0.6 | 18 | 6.590 |
| Goldfish (*Carassius auratus auratus*) | 0.9 | 18 | 10.700 |
| Green sunfish (*Lepomis cyanellus*) | 0.8 | 18 | 0.146 |
| Bluegill (*Lepomis macrochirus*) | 0.4 | 29 | 0.020 |
| | 0.4 | 29 | 0.070[a] |
| Largemouth bass (*Micropterus salmoides*) | 0.9 | 18 | 0.285 |
| Walleye (*Stizostedion vitreum*) | 1.3 | 18 | 0.064 |
| Yellow perch (*Perca flavescens*) | 1.4 | 18 | 0.263 |
| *Tilapia* sp. | 0.8 | 24 | 2.00 |
| **Invertebrates:** | | | |
| Daphnid (*Daphnia magna*) | 1st instar | 21 | 0.001[b] |
| Sowbug (*Asellus brevicaudus*) | Mature | 21 | 3.00 |
| Scud (*Gammarus fasciatus*) | Mature | 21 | 0.00076 |
| Grass shrimp (*Palaemonetes kadiakensis*) | Mature | 21 | 0.032 |
| Stonefly (*Pteronarcella badia*) | 2nd year class | 15 | 0.0011 |
| Caddisfly (*Limnephilus sp.*) | Juvenile | 15 | 0.0013 |
| American oyster (*Crassostrea virginica*) | Egg | — | 9.070[c,d] |
| **Amphibians:** | | | |
| Fowler's toad (*Bufo woodhousei fowleri*) | Tadpole | 15 | 0.420 |
| Western chorus frog (*Pseudacris triseriata triseriata*) | Tadpole | 15 | 0.200 |
| | Tadpole | 15 | 0.560[a] |

[a] 24-hour $LC_{50}$.
[b] 48-hour $EC_{50}$.
[c] 48-hour median threshold limit (TLM).
[d] Desi et al., 1975/76; as cited in Verschueren, 1983.

Source: Mayer and Ellersieck, 1986.

## Aquatic Invertebrates

The aquatic invertebrates most acutely sensitive to malathion are scuds (amphipods), stoneflies, and caddisflies. (See table B5-1.) Field studies support the finding that scuds are sensitive to malathion.

On study sites in Wyoming treated with 0.5 lb a.i./acre of malathion, populations of the amphipod *Hyalella azteca* (Saussure) were nearly extirpated and showed no recovery after 1 year (Pfadt et al., 1985). However, the results of sensitivity studies of some aquatic invertebrates differ between laboratory and field population studies. For example,

laboratory populations of shrimp have been shown to be highly sensitive to malathion (Hunsen et al., 1973; as cited in Dobroski and Lambert, 1984), while field studies of insecticide exposure to various crustacean species, including shrimp and plankton, showed no effect on the organisms at application rates for mosquito control (application rate not specified) (Tapatz et al., 1974; Wall and Marganian, 1971; all as cited in Dobroski and Lambert, 1984).

At concentrations effective for the large-scale control of rice and sugar cane pests (application rate not specified), malathion exposure had no effect on red crawfish (Muncy and Oliver, 1963; as cited in Dobroski and Lambert, 1984). Although populations of various insect families (Chironomidae, Ceratopogonidae, Sciaridae, and Empidae) and orders (Collembola, Plecoptera, and Ephemeroptera) have been reduced by the aerial application of malathion (Kennedy and Walsh, 1970; Cope, 1966; Giles, 1970; Sanders and Cope, 1968; all as cited in Dobroski and Lambert, 1984), it was noted that such reductions are probably temporary, and a rapid recovery would be expected in these aquatic populations (Dobroski and Lambert, 1984).

### Aquatic Plants

No adverse effects of malathion on aquatic plants have been reported. Algae metabolize malathion rapidly, and the degradation products are not harmful (Mulla and Mian, 1981). Field studies of ULV applications of malathion to a salt marsh resulted in no adverse effects to aquatic plants (Tagatz et al., 1974; as cited in Dobroski and Lambert, 1984).

### Amphibian and Reptile Toxicity

Malathion is toxic to Fowler's toad and western chorus frog tadpoles. The 96-hour $LC_{50}$s are 0.420 mg/L for Fowler's toad tadpoles and 0.200 mg/L for western chorus frog tadpoles (Mayer and Ellersieck, 1986). Also, a 24-hour $LC_{50}$ of 0.560 mg/L has been reported for western chorus frog tadpoles (Mayer and Ellersieck, 1986). (See table B5-1.) No additional data on toxicity to amphibians and reptiles were found.

## Azinphos-methyl

### Mammalian Toxicity

Azinphos-methyl is highly toxic to mammals. The acute oral $LD_{50}$ for mice and guinea pigs is 15 mg/kg (National Library of Medicine, 1988) and 80 mg/kg (Smith, 1987), respectively. The mule deer has an acute oral $LD_{50}$ of 32 mg/kg (Hudson et al., 1984).

When azinphos-methyl was added to the diet of horses at up to 0.5 mg/kg/day (25 ppm) in the feed for 7 days, no changes in erythrocytic and plasma cholinesterase levels were observed. Dose-dependent decreases in erythrocytic and plasma cholinesterase levels occurred in 7-day tests of doses of 1, 1.5, and 2 mg/kg/day (50, 75, and 100 ppm/day). After dosing was completed, plasma cholinesterase levels recovered rapidly to pretreatment levels, while erythrocytic

cholinesterase levels recovered more slowly (Giri et al., 1974; as cited in Lambert, 1985).

Lambert (1985) reports that newborn calves, yearling cattle, sheep, and goats tested by McCarthy et al. (1969; as cited in Lambert, 1985) had minimum toxic oral doses of 0.5, 2.5, 5, and 2.5 mg/kg, respectively.

**Avian Toxicity**

Azinphos-methyl is moderately toxic to birds (EPA, 1986a). Acute oral toxicity $LD_{50}$s are 136 mg/kg for mallard ducks and 60 mg/kg for bobwhite quail (Hudson et al., 1984). Red-winged blackbirds have an acute oral $LD_{50}$ of 8 mg/kg (Shafer, 1983). Chickens have an acute oral $LD_{50}$ of 277 mg/kg (NIOSH, 1987).

The dietary $LC_{50}$ for the Japanese quail is 935 ppm (Hill and Camardese, 1986). The dietary $LC_{50}$s for the northern bobwhite, the ring-necked pheasant, and the mallard are 488, 1,821, and 1,940 ppm, respectively (Hill et al., 1975; as cited in Smith, 1987).

Experimentation indicates that northern bobwhite quail are more sensitive to azinphos-methyl than Japanese quail. Both quail were fed azinphos-methyl by Gough et al. (1967; as cited in Lambert, 1985) at levels ranging from 20 to 4,800 ppm a.i. by weight of feed. Birds receiving 1,620 and 4,800 ppm showed 100 percent mortality. Northern bobwhite showed 80 percent mortality at 540 ppm and 30 percent mortality at 180 ppm, while Japanese quail exhibited normal mortality rates at these levels. Hatching of viable eggs was markedly reduced and delayed in Japanese quail fed 540 ppm of azinphos-methyl, and growth of northern bobwhite was reduced at all dosages.

Azinphos-methyl frequently did not prove toxic to birds in field tests. In one field test, caged northern bobwhite sprayed with a ULV application of 1 lb a.i./acre showed no symptoms of toxicity in periodic observations during the month following application (Nelson and Shipp, 1967; as cited in Anderson et al., 1974). Anderson et al. (1974) also reported a similar study in which two applications of 0.75 lb a.i./acre followed by four applications of 1 lb a.i./acre were made on a 4,500-acre area (Sinclair, 1968). The applications were made at intervals of 6 to 16 days over a period of 2 months. Caged northern bobwhite in the treated area showed no adverse effects caused by the sprays or ingestion of feed left uncovered during spraying. No ill effects were observed in mourning doves and shorebirds inhabiting the immediate environs of a large stock tank within the treated area.

Penned pheasants showed no harmful effects after treatment with a dilute spray containing azinphos-methyl at the relatively high rate of 5 lb a.i./acre. The reproductive success of pheasants sprayed with azinphos-methyl did not differ significantly from that of control birds (DOI, 1967; as cited in Anderson et al., 1974).

In a study of chickens, azinphos-methyl failed to produce delayed neurotoxic symptoms after application of a single, highly toxic dose.

Azinphos-methyl was also introduced in the diet of chickens at 158, 210, 263, and 315 mg/kg/day (900, 1,200, 1,500, and 1,800 ppm/day) in 30-day feeding studies. No delayed neurotoxic effects or histologic injuries were observed (Kimmerle and Loser, 1974; as cited in Lambert, 1985).

There is evidence to indicate that azinphos-methyl does not accumulate in aquatic environments to levels that may be detrimental to waterfowl. Five mallard ducks placed in 0.0315-acre ponds that had been sprayed six times with Guthion at the rate of 0.4 lb a.i./acre azinphos-methyl remained active and healthy and developed normally (U.S. Department of the Interior, 1963; as cited in Anderson et al., 1974).

## Invertebrate Toxicity

### Honey Bees

Azinphos-methyl is highly toxic to honey bees. The contact toxicity $LD_{50}$ is 0.000063 mg/bee, and the acute oral toxicity $LD_{50}$ is 0.00015 mg/bee (Stevenson and Walker, 1976; as cited in Lambert, 1985). Field studies reflect this high toxicity.

Needham and Stevenson (1973) tested the effects of azinphos-methyl, endosulfan, and malathion on honey bees. Bee colonies were located at the edge of 9.9-acre plots on fields of oil seed rape in full flower. A 22-percent emulsifiable concentrate formulation of azinphos-methyl sprayed at 0.410 lb a.i./acre was second only to malathion (60-percent emulsifiable concentrate formulation) in number of bees killed after tractor spray applications and accounted for 32 percent of the total dead bees collected at the test hives 1 day after treatment.

Another experiment reported in the same study (Needham and Stevenson, 1973) compared the effects of wettable powder and emulsifiable concentrate formulations of azinphos-methyl and endosulfan. The wettable powder formulation was more toxic than the emulsifiable concentrate formulation for both chemicals (more than twice as many dead bees were found in fields treated with wettable powder than with emulsifiable concentrate on the first day after treatment), but both formulations of azinphos-methyl killed many more bees than either endosulfan formulation.

In another field test by Atkins et al. (1970; as cited in Lambert, 1985), Guthion applied at 0.5 and 1.5 lb a.i./acre azinphos-methyl killed 100 percent of caged bees directly exposed to aerial spray during application. Mortality in caged bees introduced to the treated fields 2 hours after treatment was 2 to 6 percent.

### Other Invertebrates

Azinphos-methyl is toxic to insect pests and beneficial invertebrates, although some selectivity has been observed. Martinez and Pienkowski (1983) found that, of six insecticides tested, azinphos-methyl had the highest selectivity ratio for the predator *Reduviolus americoferus*

(Carayon) over the pest potato leafhopper. The $LD_{50}$ for *R. americoferus* was 200 ppm and for the potato leafhopper, 9 ppm. In addition, the tarnished plant bug, an alternate prey for *R. americoferus*, had an intermediate toxicity $LD_{50}$ of 68 ppm. Thus, in this case, azinphos-methyl shows the desirable quality of being more toxic to a pest species than to the pest's predator or the predator's alternate food source.

Meyerdirk et al. (1979; as cited in Lambert, 1985) conducted a pesticide sensitivity study on parasites and predators of the citrus mealybug, a serious pest in many grapefruit orchards in the Lower Rio Grande Valley of Texas. The study showed that azinphos-methyl combined with citrus oil had the highest relative toxic residual activity over the longest time period and for the most species tested. Azinphos-methyl with citrus oil, compared with four other pesticide compounds, was the most toxic compound on both the 1st and 35th day after treatment to the four parasites (*Pauridia peregrina, Leptomastix dactylopii, Leptomastidea abnormis*, and *Angyrus pseudococci*) and two predators (*Cryptolaemus montrouzieri* and *Sympherobius barberi*) tested.

Azinphos-methyl caused high mortality in several life stages of the aphid predator *Aphidoletes aphidimyza* (Rondan) (Warner and Craft, 1982; as cited in Lambert, 1985). Differences in susceptibility occurred between different strains and between field-collected and laboratory-reared strains. Field populations appeared to develop a low-level resistance to azinphos-methyl.

**Plant Toxicity**

The available data indicate that azinphos-methyl is generally nontoxic to plants. It is registered for use as an insecticide on fruit trees, ornamental plants, vegetable crops, and cotton. Guthion 2S and 2L may, however, injure American linden (*Tilia americana*) and hawthorn (*Crataegus* spp.) (Mobay Corporation, undated) when applied at high ambient temperatures (greater than 80°F) or to trees under stress of disease or heavy insect infestation (oral communication, Mobay marketing department, Kansas City, Missouri, January 18, 1989).

Radiolabeled azinphos-methyl residues were absorbed through the roots and translocated to the shoots of hydroponically treated plants; no toxic effects were reported (EPA, 1986a).

Because azinphos-methyl is highly toxic to honey bees, it may indirectly harm pollinator-dependent vegetation by reducing honey bee populations.

**Aquatic Species Toxicity**

The acute toxicity of azinphos-methyl to fish, aquatic invertebrates, and the aquatic stages of amphibians, as indicated by 96-hour $LC_{50}$ values, is shown in table B5-2.

### Fish

Fish species vary greatly in their response to azinphos-methyl. Available data indicate that azinphos-methyl ranges from very highly toxic

**Table B5-2. Acute Toxicity of 93 Percent Technical Grade AZINPHOS-METHYL to Aquatic Organisms**

| Organism | Stage or weight (g) | Water temperature (°C) | 96-hour $LC_{50}$ (mg/L) |
|---|---|---|---|
| **Fish:** | | | |
| Channel catfish (*Ictalurus punctatus*) | 1.5 | 18 | 3.29 |
| Black bullhead (*Ictalurus melas*) | 1.7 | 18 | 3.50 |
| Fathead minnow (*Pimephales promelas*) | 1.2 | 18 | 0.235 |
| Carp (*Cyprinus carpio*) | 0.6 | 18 | 0.695 |
| Goldfish (*Carassius auratus auratus*) | 0.9 | 18 | 4.270 |
| Green sunfish (*Lepomis cyanellus*) | 1.1 | 18 | 0.052 |
| Bluegill (*Lepomis macrochirus*) | 0.9 | 24 | 0.0041 |
| Largemouth bass (*Micropterus salmoides*) | 0.9 | 18 | 0.0048 |
| Black crappie (*Pomoxis nigromaculatus*) | 1.0 | 18 | 0.0030 |
| | 1.0 | 18 | 0.0047[a] |
| Yellow perch (*Perca flavescens*) | 0.90 | 22 | 0.0024 |
| **Invertebrates:** | | | |
| Sowbug (*Asellus brevicaudus*) | Mature | 15 | 0.021 |
| Scud (*Gammarus fasciatus*) | Mature | 15 | 0.00010 |
| Crayfish (*Procambarus* sp.) | Immature | 12 | 0.056 |
| Stonefly (*Pteronarcys californica*) | 2nd year class | 15 | 0.0019 |
| American oyster (*Crassostrea virginica*) | Egg | — | 0.620[b,c] |
| **Amphibians:** | | | |
| Fowler's toad (*Bufo woodhousei fowleri*) | Tadpole | 15 | 0.109 |
| | Tadpole | 15 | 0.710[a] |
| Western chorus frog (*Pseudacris triseriata triseriata*) | Tadpole | 15 | 3.20 |

[a] 24-hour $LC_{50}$.
[b] 48-hour median threshold limit (TLM).
[c] Davis and Hidu, 1969; as cited in Verschueren, 1983.

Source: Mayer and Ellersieck, 1986

to moderately toxic to freshwater fish—with $LC_{50}$ values ranging from 0.0024 mg/L to 4.270 mg/L, depending on the species tested, with most values in the very highly toxic range (less than 0.1 mg/L) (EPA, 1986a). Bluegills, sunfish, crappie, perch, and bass are considerably more sensitive to azinphos-methyl than are black bullhead, channel catfish, or goldfish (Anderson et al., 1974). See table B5-2.

Symptoms of azinphos-methyl toxicity in fish include erratic swimming accompanied by uncontrolled convulsions at varying intervals. Rapid gill movements followed by paralysis and death occur in rapid succession.

In one field study, a 0.75-acre pond known to contain brood channel catfish, as well as an abundance of other species, was exposed to one application of azinphos-methyl at 0.25 mg a.i./L. An estimated 1,500 green sunfish, 200 bluegills, 100 crappies, and 150 threadfin shad were killed, but there were no apparent effects on catfish (Meyer, 1965).

In a Texas experiment, aerial applications of azinphos-methyl to shallow farm ponds using rates of 0.188 to 0.25 lb a.i./acre caused serious mortality of largemouth bass and red-ear sunfish, while green sunfish, channel catfish, black bullheads, and cyprinids were not affected (Campbell, 1968; as cited in Anderson et al., 1974). Mulla et al. (1967; as cited in Lambert, 1985) noted in a tank study that mature carp showed initial distress, then recovery, when exposed to 1 mg/L of azinphos-methyl. All fish were killed at 1.5 mg a.i./L. In a study that exposed carp embryos to selected pesticides, Malone and Blaylock (1970; as cited in Lambert, 1985) found that the lowest concentration of azinphos-methyl that significantly increased mortality was 1 mg a.i./L. Fry retained in azinphos-methyl solutions at 0.1 mg/L were killed within 48 hours even though this concentration did not affect embryo viability.

In a study by Macek and McAllister (1970; as cited in Lambert, 1985), 12 species of fish were tested against nine insecticides, including azinphos-methyl. Members of the families Centrarchidae (sunfish, bluegill, bass) and Salmonidae (Rainbow trout, brown trout, coho salmon) were more susceptible to Guthion and had lower 96-hour $LC_{50}$ values (very highly toxic) than members of Cyprinidae (goldfish, minnow, carp) and Ictaluridae (catfish), which had 96-hour $LC_{50}$s in the moderately toxic range.

### Aquatic Invertebrates

Azinphos-methyl is very highly toxic to freshwater aquatic invertebrates with 96-hour $LC_{50}$ values varying from 0.00010 to 0.056 mg/L, depending on the species tested (Nebeker and Gaufin, 1964; Gaufin et al., 1965; Jensen and Gaufin, 1966; Sanders and Cope, 1968; Sanders, 1969, 1972; all as cited in EPA, 1986b). See table B5-2.

Sklar (1985), investigating the potential effect that runoff of azinphos-methyl from Louisiana plantations might have on commercially important crayfish populations in surrounding wetland habitats, found that the 48-hour acute oral $LD_{50}$ for adult crayfish is 1.9 mg/kg. While a dietary level of 25 ppm Guthion in crayfish food for 8 months did not affect growth rates, treated crayfish began to die 2 to 3 months before their control counterparts.

Grass shrimp exposed to azinphos-methyl in a continuous flow bioassay had 5- and 20-day $LC_{50}$ values of 0.0012 and 0.00016 mg/L, respectively (Sanders, 1972; as cited in EPA, 1986b). The amphipod *Gammarus fasciatus* was the most sensitive organism tested with a 96-hour $LC_{50}$ of 0.00010 mg/L. Jensen and Gaufin (1966; as cited in EPA, 1986b)

observed 96-hour and 30-day $LC_{50}$ values of 0.002 and 0.00024 mg/L, respectively, for the stonefly naiad *Acroneuria pacifica*, and 0.0046 and 0.0013 µg/L, respectively, for the stonefly naiad *Pteronarcys californica* (EPA, 1986b).

In a study by Naqui and Ferguson (1970; as cited in Lambert, 1985), the $LC_{50}$s of freshwater shrimp collected from three water bodies subject to azinphos-methyl contamination from cotton fields in Mississippi were compared to that of shrimp from an uncontaminated lake. Shrimp from two of the three azinphos-methyl-exposed water bodies showed higher 24-hour $LC_{50}$s (0.0168 and 0.105 mg/L) than that of shrimp from the uncontaminated lake (0.0088 mg/L). Gas chromatographic analyses of the shrimp revealed no detectable insecticide residue; thus, in this case, increases in insecticide tolerance did not mean increased bioaccumulation.

Zooplankton populations, especially copepods, may be substantially reduced by azinphos-methyl, but Meyer (1965) reports that they quickly return to pretreatment levels.

### Aquatic Plants

There are no studies available on azinphos-methyl's effect on aquatic vegetation.

### Amphibian and Reptile Toxicity

Western chorus frog tadpoles, with a 96-hr $LC_{50}$ of 3.20 mg/L, are more tolerant of azinphos-methyl than Fowler's toad tadpoles, which have a 96-hour $LC_{50}$ of 0.109 mg/L (Mayer and Ellersieck, 1986). Also, a 24-hour $LC_{50}$ of 0.710 mg/L has been reported for Fowler's toad tadpoles (Mayer and Ellersieck, 1986). (See table B5-2.) No additional data on toxicity to amphibians and reptiles were found.

## Diflubenzuron

### Mammalian Toxicity

Diflubenzuron has a low toxicity to mammals. The acute oral $LD_{50}$ for rats is greater than 4,640 mg/kg (EPA, 1987).

Field applications of Dimilin® to a boreal forest at levels of 0.0625 lb/acre, 0.125 lb/acre, and 0.25 lb/acre showed no adverse effects on small mammals (Brown and Dimond, 1976).

### Avian Toxicity

Diflubenzuron has a low toxicity to birds. For northern bobwhite and mallards, the oral acute toxicity is greater than 5,000 mg/kg and the dietary toxicity is greater than 20,000 ppm (EPA, 1987). Diflubenzuron intoxication is indicated by anorexia on the day after treatment. Mallards have an $LD_{50}$ of greater than 2,000 mg/kg (Hudson et al., 1984).

The low avian toxicity of diflubenzuron is supported by field observations. In an experimental aerial application of Dimilin at

0.0783 lb a.i./acre on a 600-acre plot, no effects on forest songbirds, including those in the families Parulidae, Turidae, and Fringillidae, were observed (Buckner et al., 1975).

In northeastern Oregon, experimenters found no sick or dead birds and did not observe any abnormal behavior in forest birds (dusky and Hammond's flycatchers, mountain chickadee, western tanager, pine siskin, dark-eyed junco, and chipping sparrow) after diflubenzuron was aerially applied to eleven 129.5-ha (320-acre) forest plots at rates of 0.0313 lb a.i./acre and 0.0625 lb a.i./acre (Richmond et al., 1979). Other field studies of diflubenzuron showed no adverse effects on wild birds (EPA, 1979).

Diflubenzuron elicited no adverse reproductive effects in northern bobwhite at feeding levels up to 250 ppm (EPA, 1979).

Poultry fed diflubenzuron secreted diflubenzuron into their eggs and retained it in muscle, liver, fat, and kidney tissues. Leghorn chickens accumulated diflubenzuron residues at twice the levels found in New Hampshire strain chickens. No effects to eggs or chicks were mentioned (EPA, 1979).

## Invertebrate Toxicity

### Honey Bees

Diflubenzuron is considered relatively nontoxic to honey bees, with an acute toxicity of greater than 0.1148 mg/bee (EPA, 1987).

Field observations support the relative nontoxicity of diflubenzuron. No effects were observed in colonies of domestic honey bees in the path of an experimental aerial application of Dimilin at 0.0783 lb a.i./acre on a 600-acre forest plot. Mortality, development of larvae, and honey production of bees in the test plot were normal or equivalent to that of bees in control plots (Buckner et al., 1975).

Another study showed no indication that eight field applications of Dimilin at rates of 0.125 lb a.i./acre and 0.0313 lb a.i./acre had any effect on bee colonies. There was no noticeable change in the rate of brood development or in the ratio of sealed and unsealed broods. No diflubenzuron residues were detected in the wax or honey from either plot. However, bee exposure to diflubenzuron residues in this experiment was limited by factors such as small plot size, competing pollen and nectar sources nearby, and the natural tendency of foraging bees to disperse (Robinson, 1979).

Honey bees fed Dimilin at 59 ppm in sugar syrup showed a decreased production in sealed brood, while dosages of 5.9 ppm and 0.59 ppm had no effect. While the concentration required for brood reduction was comparatively high, these results show that diflubenzuron cannot be considered nonhazardous (Barker and Taber, 1977).

### Other Invertebrates

Results of diflubenzuron on invertebrates vary. In cotton fields treated with 0.0313 lb a.i./acre to 0.125 lb a.i./acre diflubenzuron, the predatory insect complex was not adversely affected (Harding and Wolfenbarger, 1980). Another study showed that populations of arthropod predators *Geocoris punctipes* (Say), *Nabis* spp., *Hippodamia convergens* (Guerin), *Coleomegilla maculata* (Debeer), *Orius insidiosus* (Say), *Chrysopa* spp., and Araneida decreased, but not significantly, in diflubenzuron-treated fields compared to untreated fields. Only *C. maculata* showed a significant decrease in numbers in this study in which diflubenzuron was applied at 0.125 lb a.i./acre. Reproduction was affected in *H. convergens*, with egg hatch significantly lower in females from diflubenzuron-treated fields for 6 days after application (Keever et al., 1977).

## Plant Toxicity

The available data suggest that diflubenzuron is generally nontoxic to plants. Diflubenzuron is registered for use on trees, shrubs, ornamental plants, mushrooms, soybeans, and cotton (Uniroyal Chemical Company, undated). Diflubenzuron has been found to be taken up in several plant species (EPA, 1979). Most radio-labeled material was found in the aerial portions of growing plants. Low levels of diflubenzuron have also been found in cottonseed after applications to cotton fields; toxic effects were not reported (USDA/State, 1978; Bull and Ivie, 1978; both as cited in EPA, 1979).

Because diflubenzuron is relatively nontoxic to honey bees, it appears that it does not pose an indirect threat to plants through their pollinators.

## Aquatic Species Toxicity

The acute toxicity of diflubenzuron to fish and aquatic invertebrates, as indicated by 96-hour $LC_{50}$ values, is shown in table B5-3.

### Fish

Diflubenzuron has exceptionally low toxicity to fish (Mulla et al., 1979). Rainbow trout, channel catfish, fathead minnows, and bluegills had relatively high 96-hour $LC_{50}$ levels, ranging from 240 mg/L for the rainbow trout to 660 mg/L for bluegills (Julin and Sanders, 1978). Julin and Sanders (1978) found the 96-hour $LC_{50}$ for the fathead minnow to be 430 mg/L, while EPA (1987) lists its acute toxicity as greater than 500 mg/L. See table B5-3.

In another study, juvenile brown bullheads and small sunfish showed no toxic effects to 22-week exposures of up to 125 mg/L of diflubenzuron (Buckner et al., 1975). According to Mulla et al. (1979), actual exposure to such high concentrations of diflubenzuron, more than 100 mg/L, is unlikely.

Indirect effects of diflubenzuron on fish have been observed in the field. For instance, after a 0.005-mg/L application of diflubenzuron to a

**Table B5-3. Acute Toxicity of 25 Percent Wettable-Powder-Formulation DIFLUBENZURON to Aquatic Organisms**

| Organism | Stage or weight (g) | Water temperature (°C) | 96-hour $LC_{50}$ (mg/L) |
|---|---|---|---|
| **Fish[a]:** | | | |
| Rainbow trout (*Salmo gairdneri*) | 1.2 | 12 | 240 |
| Channel catfish (*Ictalurus punctatus*) | 2.2 | 22 | 370 |
| Fathead minnow (*Pimephales promelas*) | 0.87 | 22 | 430 |
| Bluegill (*Lepomis macrochirus*) | 0.5 | 22 | 660 |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | Mixed | — | 0.0015[b,c] |
| Scud (*Gammarus pseudolimnaeus*) | Mature | 12 | 0.025[d] |
| Stonefly (*Skwala* sp.) | 1st year class | 7.0 | 57.5[d] |

[a] Julin and Sanders, 1978.
[b] Miura and Takahashi, 1974.
[c] 48-hour $EC_{50}$ with technical material.
[d] Mayer and Ellersieck, 1986.

Note: *Salmo gairdneri* is the former Latin name for rainbow trout. As of 1990, the new Latin name is *Oncorhynchus mykiss*.

California lake, bluegills switched from eating mostly cladocerans and copepods to chironomid midges and terrestrial insects. Fish growth was not altered by the treatment (Apperson et al., 1978).

In another field study, populations of mosquitofish (*Gambusia affinis*) and flagfish (*Jordanella floridae*), increased after repeated applications of diflubenzuron in a Louisiana marsh. This effect was more likely the result of an increase in diflubenzuron-resistant invertebrate prey organisms resulting from removal of diflubenzuron-susceptible nonprey competitors than to any direct effect of diflubenzuron (Farlow et al., 1978).

Booth and Ferrel (1977) studied whether diflubenzuron residues in benthic sediments might affect fish. Channel catfish did not bioaccumulate Dimilin residues from treated sediments in a simulated lake ecosystem constructed in the laboratory.

## Aquatic Invertebrates

While diflubenzuron may have low toxicity to mammals, birds, insects, and fish, it is extremely toxic to crabs, shrimp, and other aquatic invertebrates (Uniroyal Chemical Company, undated). Diflubenzuron disrupts the development and reproduction of crustaceans and other aquatic invertebrates by causing death during the molting process. Susceptible organisms die while trying to molt because the new

exoskeleton is not properly formed. Growing larvae generally are more susceptible than adults.

A recent study on the acute toxicity of diflubenzuron to various life stages of the grass shrimp showed that larvae and post larvae were the most sensitive, with 96-hour mean $LC_{50}$s of 0.00144 and 0.00162 mg/L, respectively. Diflubenzuron was considerably less toxic to adult grass shrimp, which recorded a mean $LC_{50}$ of 6.985 mg/L (Wilson and Costlow, 1987). Grass shrimp larvae were more sensitive to diflubenzuron exposure than juvenile *Mysidopsis bahia* and *Rhithropanopeus harrisii,* which recorded 96-hour $LC_{50}$s of 0.0021 and 0.0064 mg/L, respectively (Nimmo et al., 1979; Christiansen et al., 1978; both as cited in Wilson and Costlow, 1987).

When applied at mosquito control rates in the field, diflubenzuron causes toxic effects in certain members of the plankton community and no observable effects in others. When diflubenzuron was applied to water at a rate of 0.025 lb a.i./acre (an effective mosquito larvicide rate), substantial immediate toxic effects were observed on water fleas, mayfly nymphs, and midges, but these populations recovered (Miura and Takahashi, 1975). Corixid and notonectid nymph populations were not significantly affected, and spiders showed no apparent effects. Miura and Takahashi (1976) conclude that no deleterious effects were observed in nontarget lake organisms after eight consecutive treatments with diflubenzuron for 2 years.

In contrast to the crustaceans, horseshoe crab larvae appear to be much more resistant to diflubenzuron (Weis and Ma, 1987). Severe mortality after molting occurred when horseshoe crab larvae were exposed to 0.050 mg/L of diflubenzuron. A slight delay in molting but no significant mortality was observed in crab larvae exposed to diflubenzuron at 0.005 mg/L.

Delayed molting and mortality at molting also were observed in fiddler crabs exposed to 0.0050 and 0.050 mg/L of diflubenzuron. Continuous exposure produced a dose-dependent retardation of limb regeneration, and lesions were observed on regenerated limbs of crabs surviving ecdysis. The presence of sediment in the container with the crab may have diluted the effects of ingestion of the pesticide, but it did not eliminate those effects (Weis et al., 1987).

### Aquatic Plants

Diflubenzuron is rapidly taken up and degraded by the blue-green algae *Plectonema boryanum* (Booth and Ferrell, 1977).

## Amphibian and Reptile Toxicity

Data on diflubenzuron's effect on amphibians and reptiles were not found in a search of the available literature.

# Methyl Parathion

## Mammalian Toxicity

The methyl parathion oral $LD_{50}$ values for rabbits and mice are 420 and 23 mg/kg, respectively (NIOSH, 1983; as cited in EPA, 1984). The oral $LD_{50}$ for dogs is 90 mg/kg (Hirschelmann and Bakemeier, 1973; as cited in EPA, 1984).

There are few other accounts of methyl parathion toxicity in mammals. A study of methyl parathion poisoning in mink concluded that the animals died of starvation rather than organophosphate contamination (Aulerich et al., 1987). The mink rejected primary (unmetabolized) and secondary (metabolized by prey organisms) food sources tainted with methyl parathion, a compound with a pungent odor, which may discourage feeding. Overall, methyl parathion may pose little direct threat to species that similarly reject tainted food sources, according to Aulerich et al. (1987).

With an oral $LD_{50}$ of 372 mg/kg, methyl parathion is moderately toxic to brown bats (*Myotis lucifugus*). However, the bats exhibited a loss of coordination after exposure and were unable to right themselves for normal flight. A methyl parathion-induced loss of flying ability may compromise competitive balance in natural bat populations (Clark, 1986).

## Avian Toxicity

The oral $LD_{50}$ of methyl parathion for female mallards is 6.60 mg/kg and 10 mg/kg for male mallards (Hudson et al., 1984). The oral $LD_{50}$ for another genetic line of mallards (mm, or Max McGraw Wildlife Foundation Mallards) is 60.5 mg/kg, while the $LD_{50}$ values for the bobwhite and pheasant are 7.56 and 8.21 mg/kg, respectively (Hudson et al., 1984). Also, the $LD_{50}$ value for the red-winged blackbird is 10 mg/kg (Schafer, 1972; as cited in Smith, 1987) and 3.08 mg/kg for the American kestrel (Rattner and Franson, 1984; as cited in Smith, 1987). Signs of intoxication include polydipsia, regurgitation, ataxia, falling, dyspnea, salivation, withdrawal, using wings for pedestrian locomotion, mutation, lacrimation, asynergy, immobility, convulsions, wing-beat convulsions, and opisthotonos (Hudson et al., 1984).

The dietary $LC_{50}$ for the Japanese quail is 69 ppm (Hill and Camardese, 1986), and the dietary $LC_{50}$ for the common grackle is 240 ppm (Grue, 1982; as cited in Smith, 1987). The dietary $LC_{50}$s for the northern bobwhite, the ring-necked pheasant, and the mallard are 90, 91, and 336 ppm, respectively (Hill et al., 1975; as cited in Smith, 1987).

Mallards exposed to methyl parathion through their feet recorded a percutaneous $LD_{50}$ of 53.6 mg/kg (Hudson et al., 1979).

Methyl parathion has not been conclusively linked with direct reproductive impairment in laboratory studies, although some studies have noted significant depression in brain ChE activity. However, field studies have suggested that methyl parathion may affect avian reproductive success (EPA, 1986c).

## Invertebrate Toxicity

### Honey Bees

Methyl parathion is highly toxic to bees and can cause substantial losses, particularly if the bees are exposed to direct treatment or to insecticide residues on crops and other blooming plants (Pennwalt Corporation, 1987; McLaren et al., 1987). Hybrids of Italian and African bees had a low $LD_{50}$ value of 0.000061 mg/bee, although these hybrids were reported to be more sensitive than California bees (De Batista et al., 1975).

As summarized in McLaren et al. (1987), microencapsulated methyl parathion is particularly hazardous to honey bees (*Apis mellifera* L.). The size of the spherical nylon microcapsules containing methyl parathion is very similar to numerous pollen types. When microencapsulated (ME) methyl parathion is sprayed over blooming plants, bees collect pollen contaminated with the microcapsules and ultimately store it in broodnest combs. Unlike liquid methyl parathion, the ME formulation has a long residual life and, when packed into the combs, the microcapsules are potentially hazardous for months after the application. Young bees and larvae are thus subject to increased exposure and potentially greater toxic effects from ME insecticide applications (Johansen and Kious, 1978; Atkins et al., 1978; Johansen, 1979; Stoner, 1978, 1979; Barker et al., 1979; Burgett and Fisher, 1977, 1980; Rhodes et al., 1979, 1980; all as cited in McLaren et al., 1987).

A comparative study of ME methyl parathion and the liquid emulsifiable concentrate (EC) form showed significantly higher mortality to bees foraging for pollen on ME-treated artificial flowers. Although both the ME and EC treatments exhibited high mortality on day 1 of the experiment, thereafter bee mortality for the EC treatment was not significantly different than the untreated controls' death rate, while the ME treatment continued to show an elevated mortality rate (McLaren et al., 1987).

Populations of honey bees may escape serious damage if colonies are removed from target areas before application of liquid or dust methyl parathion formulations. In Arizona cotton fields, for example, honey bee losses were reduced by moving colonies from the fields for 1 to 4 days during aerial application of the insecticide (Moffett et al., 1981).

Honey bee colonies may also be protected within the target areas. In the Arizona study, honey bee populations were protected from methyl parathion exposure by confining the colonies to ramadas (hive shelters) for 24 hours or more, providing water and pollen feed, shading the colonies with burlap, and placing Miller bottom boards beneath the

ramadas. All colonies receiving this combined treatment survived the aerial sprayings, while in the unprotected controls, only 1 of 10 colonies survived (Moffett et al., 1981).

### Other Invertebrates

Methyl parathion is toxic to many species of hemipteran predators commonly found in southwestern cotton fields. These insects are predaceous on various types of agricultural pests, including plant bugs, leafhoppers, aphids, thrips, spider mites, and lepidopteran eggs and larvae (Pape and Crowder, 1981).

A study of beneficial hemipteran insects in central Arizona concluded that topical applications of methyl parathion were highly toxic to the species *Nabis alternatus* (Parshley), *Nabis americoterus* (Carayon), *Geocoris punctipes* (Say), *Geocoris pallens* (Stall), and *Orius tristicolor* (White). The ranges of $LD_{50}$ values, sampled at various locations in the study region, were 1.0 to 2.1, 0.7 to 1.3, 1.9, 2.1 to 2.4, and 0.4 to 0.6 mg/kg, respectively (Pape and Crowder, 1981).

## Plant Toxicity

Methyl parathion (ME) is registered for use on various fruit, vegetable, and field crops (including alfalfa, corn, and cotton). When tank-mixed with streptomycin, the insecticide may injure apple and pear tree fruit and foliage and, as a concentrate or semiconcentrate spray, is likely to injure D'Anjou pears (Pennwalt Corporation, 1987).

Methyl parathion is highly toxic to honey bees and may indirectly harm nearby pollinator-dependent vegetation by severely reducing pollinator populations present at the time of treatment.

## Aquatic Species Toxicity

The acute toxicity of methyl parathion to fish, aquatic invertebrates, and the aquatic stages of amphibians, as indicated by 96-hour $LC_{50}$ values, is shown in table B5-4.

### Fish

Among freshwater fish species in the United States, trout and salmon are the most sensitive to methyl parathion exposure, with 96-hour $LC_{50}$ values in a range of 1.9 to 5.3 mg/L. Yellow perch, bluegill, and largemouth bass are highly sensitive to methyl parathion and have 96-hour $LC_{50}$ values of 3.060, 4.380, and 5.220 mg/L, respectively (Mayer and Ellersieck, 1986). See table B5-4.

In an investigation of fish mortality after methyl parathion exposure, rainbow trout (*Salmo gairdneri*) were tested at insecticide concentrations of 2.1, 2.5, and 2.8 mg/L (the species' $LC_{50}$ value) over a 96-hour static exposure period. During the exposure period, mortalities of 37 percent, 38 percent, and 61 percent, respectively, were observed and all survivors were immobile and had distended abdomens. After removal from the contaminated water, significant additional mortality occurred during day 1 of the observation period, with final mortality figures of

**Table B5-4. Acute Toxicity of 90 Percent Technical Grade METHYL PARATHION to Aquatic Organisms**

| Organism | Stage or weight (g) | Water temperature (°C) | 96-hour $LC_{50}$ (mg/L) |
|---|---|---|---|
| **Fish:** | | | |
| Goldfish (*Carassius auratus auratus*) | 0.9 | 18 | 9.000 |
| Carp (*Cyprinus carpio*) | 0.6 | 18 | 7.130 |
| Fathead minnow (*Pimephales promelas*) | 1.2 | 18 | 8.900 |
| Black bullhead (*Ictalurus melas*) | 1.2 | 18 | 6.640 |
| Channel catfish (*Ictalurus punctatus*) | 1.4 | 18 | 5.240 |
| Green sunfish (*Lepomis cyanellus*) | 0.8 | 18 | 6.860 |
| Bluegill (*Lepomis macrochirus*) | 1.0 | 17 | 4.380 |
| Largemouth bass (*Micropterus salmoides*) | 0.9 | 18 | 5.220 |
| Yellow perch (*Perca flavescens*) | 1.4 | 18 | 3.060 |
| | 1.4 | 18 | 4.930[a] |
| **Invertebrates:** | | | |
| Daphnid (*Daphnia magna*) | 1st instar | 21 | 0.00014[b] |
| Daphnid (*Simocephalus serrulatus*) | 1st instar | 15 | 0.00037[b] |
| Scud (*Gammarus fasciatus*) | Mature | 15 | 0.0038 |
| Crayfish (*Orconectes nais*) | Mature | 15 | 0.015 |
| Damselfly (*Ischnura verticalis*) | Late instar | 15 | 0.033 |
| **Amphibians:** | | | |
| Western chorus frog (*Pseudacris triseriata* | Tadpole | 18 | 3.70 |
| *triseriata*) | Tadpole | 18 | 7.60[a] |
| True frog (*Rana* sp.) | Mature | — | 8.00[c] |

[a] 24-hour $LC_{50}$.
[b] 48-hour $EC_{50}$.
[c] Mudgall and Patil, 1987.

Source: Mayer and Ellersieck, 1986.

72, 83, and 98 percent, respectively. Growth of the rainbow trout, however, was not impaired by previous exposure to methyl parathion (Palawski et al., 1983).

Acetylcholinesterase activity in the freshwater fish *Tilapia mossambica* (Peters) was significantly reduced by methyl parathion exposure. A 62-percent decrease in brain AChE activity was noted, while muscle, gill, and liver tissues exhibited reductions of 41, 32, and 27 percent, respectively (Siva Prasada Rao and Ramana Rao, 1982).

### Aquatic Invertebrates

As summarized in EPA (1984), methyl parathion exposure may be more toxic to freshwater invertebrates than to fish. The 96-hour $LC_{50}$ value is 0.003 mg/L for the crayfish *Procambarus clarki,* 0.015 mg/L for the

crayfish *Orconectes nais*, and 0.0038 mg/L for the crustacean scud *Gammarus fasciatus*. The 48-hour $LC_{50}$ values for the daphnids *Daphnia magna* and *Simocephalus serrulatus* are 0.00014 and 0.00037 mg/L, respectively, while the larval stages of the damselfly and gnat have $LC_{50}$ values of 0.033 and 0.0012 mg/L (Cheah et al., 1980; Johnson and Finley, 1980; Hazeltine, 1963; all as cited in EPA, 1984). See table B5-4.

In a study of tissue respiration and ionic content in the freshwater mussel *Lamellidens marginalis*, methyl parathion exposure reduced oxygen consumption and facilitated the loss of sodium, potassium, and calcium, important osmoregulatory ions. The decreases in oxygen consumption and sodium concentration were greatest at the gills, while the potassium and calcium decreases were most pronounced at the mantle and hepatopancreas, respectively (Moorthy et al., 1984).

Marine crustaceans are also highly susceptible to methyl parathion. The 96-hour $LC_{50}$ values for the hermit crab, mysid shrimp, sand shrimp, and grass shrimp lie within a range of 0.00077 to 0.007 mg/L (EPA, 1984).

A study at California's Clear Lake observed no permanent effects on zooplankton species after three methyl parathion treatments of 0.0033 mg/L. Species of copepods and cladocerans recovered rapidly after exposure (Apperson et al., 1976; as cited in Mulla et al., 1979).

### Aquatic Plants

Methyl parathion was shown to decrease growth of green algae (*Chlorella protothecoids*) in a dose-related response experiment. At the concentrations of 30 and 40 mg/L, algal growth was completely arrested and a net loss of cells was observed (Saroja and Bose, 1982; as cited in EPA, 1984).

In another dosage-response study, marine algae (*Sheltonema costatum*) exhibited a 50-percent decrease in chlorophyll absorbance ($EC_{50}$) at the concentration of 5.3 mg/L (Walsh and Alexander, 1980; as cited in EPA, 1984).

## Amphibian and Reptile Toxicity

The 96-hour and 24-hour $LC_{50}$s for western chorus frog tadpoles are 3.70 and 7.6 mg/L, respectively (Mayer and Ellersieck, 1986). See table B5-4.

After exposure to methyl parathion, the frog *Rana cyanophlyctis* became excitable and hyperactive, with heavy foaming and mucus secretions. The 96-hour $LC_{50}$ values for male and female frogs were noted at 8 and 11.5 mg/L, respectively. At a methyl parathion concentration of 5 mg/L, *R. cyanophlyctis* exhibited a decrease in the glycogen content of liver, muscle, and kidney tissues, indicative of a higher energy demand during insecticide-induced stress. However, at a concentration of 10 mg/L, the frog's glycogen content was enhanced in all tissues (Mudgall and Patil, 1987).

# Section B6

## Nontarget Species Exposure Analysis

This section presents the methodology used to estimate exposures to terrestrial wildlife and aquatic species from the four insecticides proposed for use under the preferred alternative in the boll weevil control program. For assessing the risks to nontarget species in this environmental impact statement, exposures were calculated for a group of terrestrial wildlife and aquatic species representative of those that typically inhabit various regions of the Cotton Belt. These species represent a range of animal classes, body sizes, and diets for which biological parameters are generally available.

The following references were used in the species selection and in deriving the biological parameters for each species:

*Distribution, Life History, and Diet*

Birds: Robbins et al. (1966), Scott et al. (1977), Chapman (1966), Meyers and Johnson (1978), Wood and Niles (1978), Dickson (1978), Beal (1911), Prickett (undated).

Mammals: Schmidt and Gilbert (1978), Burt and Grossenheider (1966), Hamilton and Whitaker (1979), Hamilton (1941), Sargeant (1978), Lockie (1959), Komarek and Komarek (1938), Odum (1949), Davis (1974), Davis (1978), Davis (1979), Lowery (1974).

Reptiles and Amphibians: Conant (1958), Auffenberg and Iverson (1979), Seehorn (1982), Dickerson (1969).

*Physiology, Metabolism, Food Intake, and Weight*

Gordon et al. (1968), Hutchinson et al. (1968), Lasiewski and Dawson (1967), Kendeigh (1969), Kendeigh (1970), Lasiewski and Calder (1971), Schmidt-Nielsen (1972), Schmidt-Nielsen (1975), Sturkie (1965), Slobodkin and Richman (1961), Welty (1962), Zar (1968), Drozdz (1968), Odum (1971), Moore (1964), Altman and Dittmer (1962), Seibert (1949), Banse and Mosher (1980), Odum et al. (1962), Damuth (1981).

### Terrestrial Species

Table B6-1 lists the representative wildlife species and gives the various biological parameters used for each species in the exposure analysis. Table B6-2 lists the diet items for each representative species. Typical and extreme exposures were estimated for each representative species using conservative assumptions (those assumptions that will provide the greatest margin of safety) for routine application operations. In both the typical and extreme dose calculations, the three major routes of exposure were examined: dermal, ingestion, and inhalation.

## Table B6-1. Physiological Characteristics of Typical Representative Species

| Typical representative animals[a] | Body weight (g) | Body surface area ($cm^2$) | Body surface contacting vegetation (percent) | Percent of body groomed | Inhalation volume (L/min) |
|---|---|---|---|---|---|
| **Birds:** | | | | | |
| American kestrel | 125 | 250 | 80 | 40 | 0.0573 |
| Northern bobwhite | 170 | 307 | 78 | 36 | 0.0726 |
| Kingbird | 33 | 103 | 92 | 60 | 0.0205 |
| Kingfisher | 250 | 398 | 75 | 32 | 0.098 |
| **Mammals:** | | | | | |
| Mouse | 20 | 74 | 96 | 69 | 0.017 |
| Rabbit | 1,350 | 1,224 | 63 | 20 | 0.480 |
| Deer | 68,000 | 16,722 | 43 | 6 | 11.1 |
| Fox | 5,670 | 3,189 | 55 | 13 | 1.52 |
| Coyote | 15,500 | 6,237 | 50 | 9 | 3.40 |
| **Amphibian:** | | | | | |
| Toad | 22 | 79 | 95 | 0 | 0.007 |
| **Reptile:** | | | | | |
| Snake | 40 | 117 | 90 | 0 | 0.00334 |
| **Domestic animals:** | | | | | |
| Cow | 453,590 | 59,292 | 35 | 3 | 50.6 |
| Chicken | 2,000 | 1,591 | 61 | 17 | 0.484 |
| Dog | 13,000 | 5,715 | 50 | 10 | 3.06 |

[a] Animals represent one or more species. For example, the kingbird is a typical representative animal for the eastern and western kingbird.

**Table B6-2. Diet Items of Typical Representative Animals**

| Typical representative animals[a] | Water[b] | Grass | Forage | Seeds | Insects | Berries | Mouse | Bird | Fish |
|---|---|---|---|---|---|---|---|---|---|
| **Birds:** | | | | | | | | | |
| American kestrel | 0.05 | 0 | 0 | 0 | 20 | 0 | 32 | 0 | 0 |
| Northern bobwhite | 0.05 | 0 | 0 | 4 | 30 | 0 | 0 | 0 | 0 |
| Kingbird | 0.02 | 0 | 0 | 1 | 8 | 4 | 0 | 0 | 0 |
| Kingfisher | 0.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| **Mammals:** | | | | | | | | | |
| Mouse | 0.05 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| Rabbit | 0.05 | 110 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Deer | 1.5 | 500 | 2,000 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fox | 0.8 | 0 | 0 | 0 | 0 | 175 | 300 | 0 | 0 |
| Coyote | 0.8 | 0 | 0 | 0 | 40 | 0 | 660 | 0 | 0 |
| **Amphibian:** | | | | | | | | | |
| Toad | 0.05 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| **Reptile:** | | | | | | | | | |
| Snake | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 |
| **Domestic animals:** | | | | | | | | | |
| Cow | 58 | 12,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chicken | 0.10 | 0 | 0 | 300 | 0 | 0 | 0 | 0 | 0 |
| Dog | 0.50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

[a] Animals represent one or more species. For example, the kingbird is a typical representative animal for the eastern and western kingbird.
[b] Consumption is in liters/day for water and in grams/day for all other items.

For typical doses, dermal exposures were based on the insecticide residue levels likely to be found on vegetation leaf surfaces because the animals were assumed to seek cover during a spraying operation. Extreme dose levels were estimated by assuming that animals did not seek cover and thus received the full insecticide application rate over their entire body surface.

The dermal penetration rates used for estimating exposures to humans were used to determine mammalian wildlife dermal penetration. These rates are 8.2 percent for malathion (Feldmann and Maibach, 1974) and 15.9 percent for azinphos-methyl (Feldmann and Maibach, 1974). Dermal penetration rates for diflubenzuron and methyl parathion were assumed to be 10 percent, based on information in USDA (1984). In both the typical and extreme exposure scenarios, mammals were assumed to receive an oral dose from grooming their fur and birds were assumed to receive an oral dose from preening their feathers. This amount was then subtracted from the amount they would receive as a dermal exposure through their skin.

Typical ingestion doses were calculated from a specified percentage of each animal's daily food intake of contaminated items, as determined by body size. Thus, the percentage of contaminated food ingested decreased as body size increased because larger animals were assumed to be more far ranging in obtaining food and, therefore, would be more likely to obtain part of their diet in an area outside of the cotton field. In the extreme case, the animals were assumed to feed entirely on contaminated food items.

The contamination of water sources was also included in the calculation of ingestion doses. In the typical case, wildlife species were assumed to consume water from an onsite pond that had received insecticide concentrations from the drift residues that would accumulate 25 feet from a treated area. Exposure estimates in the extreme case were based on the consumption of water from an onsite pond that had been directly sprayed with insecticide.

Inhalation exposures were assumed to come from a hypothetical amount of insecticide droplets drifting offsite.

The total estimated dose to each animal was calculated as the sum of the doses received via the dermal, ingestion, and inhalation routes. The total typical and extreme dose estimates for the representative species are presented in section B7 of this appendix.

For honey bees, exposures were estimated by assuming that an individual bee contacts fresh insecticide residues and fully absorbs the residues.

**Exposure Calculations—Typical Dose Description**

## Dermal Exposures

Typical dermal exposures were assumed to come from two sources: (1) directly from the deposit of spray drift on the animal's body and (2) indirectly by contact with contaminated vegetation.

The exposure received from spray drift was based on the insecticide level likely to be found on vegetation leaf surfaces at a distance of 25 feet from a treated area. To estimate this residue level, a drift deposition equal to 57 percent of the application rate and a leaf area index of 4 were assumed. The direct dermal exposure to an animal was then calculated by assuming that the animal's total body surface area (BSA) is a function of its weight (BWT) (Kendeigh, 1970):

$$\text{BSA (cm}^2) = 10 \times [\text{BWT (g)}]^{0.667}$$

The direct dermal exposure (DDE) was calculated as:

$$\text{DDE (mg)} = \text{residue level (mg/cm}^2) \times \text{BSA (cm}^2)$$

Wildlife also may receive indirect dermal exposure when moving through contaminated vegetation by transferring insecticide from the vegetation to their body surface. The amount transferred depends on (1) the density of the vegetation, (2) the animal's body size in relation to the height or density of the vegetation, and (3) the amount of movement of the animal. It was assumed that a certain percentage of the animal's total body surface received insecticide residues at the level of residues on leaf surfaces. The percentage of contacted body surface was based on the animal's body size and a movement factor (MVF) to adjust for the taxonomic class. Mammals, for example, were expected to move more than amphibians. The movement factors (MVFs) for different taxonomic classes are as follows: mammals, 1; birds, 0.8; reptiles, 0.3; and amphibians, 0.4.

The animal's vegetation contact percent (VCP) was based on its body weight in grams according to the following formula:

$$\text{VCP} = 1.3\ [\text{BWT (g)}]^{-0.1}$$

The indirect dermal exposure (IND) was then calculated as follows:

$$\text{IND (mg)} = \text{Residues on leaves (mg/cm}^2) \times \text{BSA (cm}^2) \times \text{MVF} \times \text{VCP}$$

Mammals and birds groom themselves regularly and may receive an ingestion dose if their fur or feathers are contaminated. The percentage of their body surface groomed (PBG) was assumed to be a decreasing function of their body size according to the following formula:

$$\text{PBG} = 1.7\ [\text{BWT (g)}]^{-0.3}$$

No grooming was assumed for reptiles and amphibians. The oral dose for mammals and birds from grooming was subtracted from the amount of insecticide that would contribute to the animal's dermal dose.

Fur, feathers, and scales afford varying degrees of protection against dermal exposure by preventing the chemical from reaching the animal's skin; they may instead allow the chemical to dry or to be rubbed off during movement. For this reason, the mammalian dermal penetration rate for each insecticide was adjusted for the three other animal classes—birds, reptiles, and amphibians—using reasonable assumptions for the differences between the classes. Specifically, the mammalian dermal penetration rate for each of the four insecticides was multiplied by the following adjustment factors to establish dermal penetration rates (DPRs) for the terrestrial taxa: mammals, 1; birds, 0.75; reptiles, 0.15; and amphibians, 5. The amphibian factor is high because the moist, glandular skin of the amphibian also serves as a respiratory organ and is much more permeable than the skin of the other animal classes. For example, Moore (1964) estimated that 30 percent of an amphibian's body weight in water can be absorbed through its skin in 24 hours.

The typical dermal doses (TDDs) for all representative species other than the honey bee were calculated as follows:

$$\text{TDD (mg/kg)} = \{[\text{DDE (mg)} + \text{IND (mg)}] \times (1.00 - \text{PBG}) \times \text{DPR}\}/\text{BWT (kg)}$$

For honey bees, typical case dermal exposures were calculated assuming that insects absorb all of the insecticide residues on their bodies. The insecticide residues on honey bees were assumed to be a fraction of the residues found on forage, with 0.536 ppm for each pound of insecticide applied per acre.

### Ingestion Exposures

Each representative species was assumed to feed on contaminated food items according to a specified diet and to drink a specified amount of water. These diet amounts are listed in table B6-2. Diets may vary from season to season and across the species range; the diet items and amounts were chosen to be a reasonable representation of what an individual animal might consume on a certain day.

It must be noted that the representative diet items for a given species do not necessarily reflect that species' exact dietary habits in nature. Although every attempt was made to match the representative species with a reasonable assortment of its normal diet items, noncharacteristic diet items or proportions of diet items were included for some species when such items produced a higher dose than their usual food sources. This manipulation of the diet items was performed to provide the most conservative assessment of risk for nontarget wildlife and aquatic

species. For example, the diets of foxes, coyotes, and American kestrels include both birds and mice in nature. However, these representative species were assumed to feed exclusively on mice for the portions of their diets not filled by other food sources (insects, berries, etc.) because the dose for a mouse is greater than the dose for a bird on a per body weight basis. Similarly, snakes eat both toads and small birds, but only birds were listed as a representative diet item for snakes because the dose for a small bird is often higher than the dose for a toad. Because the dose for the kingbird exceeded the dose received by the toad for malathion, diflubenzuron, and methyl parathion, the representative snake species was assumed to feed exclusively on this bird.

Some diet items—grass, forage vegetation, seeds, insects, and berries—were assumed to have the following contamination levels (in ppm) from application, based on field studies by Hoerger and Kenaga (1972) for a 1-lb/acre application rate:

| Diet item | Residue (ppm/lb/acre) |
|---|---|
| Grass | 10.5 |
| Forage | 3.76 |
| Seeds | 0.353 |
| Insects | 0.536 |
| Berries | 0.182 |

For typical doses, dietary estimates were calculated assuming that part of the animal's diet was contaminated with insecticide residues. The amount of contaminated food that an animal eats is inversely proportional to its body mass because larger animals have larger home ranges and are less likely than smaller animals to feed on contaminated items at a particular site. That is, the percentage of contaminated food intake was assumed to decrease as the animal's body mass increased. The percentage of food contaminated (PFC) was based on the following formula:

$$PFC = 100 \times [1/BWT\ (g)]^{0.2}$$

Predators that feed on mice or birds were assumed to receive the total body burden that each of these prey species had received through the dermal, oral, and inhalation routes. Predators that feed on fish (piscivores) were assumed to receive residue levels based on the insecticide concentrations in water. The estimated concentration of an insecticide in water was based on the assumption that a 2-foot (0.61-m) deep pond received drift residues at a distance of 25 feet. The typical water concentrations used in the analysis were 0.123 mg/L for malathion, 0.0262 mg/L for azinphos-methyl, 0.0131 mg/L for diflubenzuron, and 0.0524 mg/L for methyl parathion. The residue levels in fish were calculated by multiplying the estimated concentration of an insecticide

in water with the insecticide's bioconcentration factor (BCF). The following BCFs were used: malathion, 37 (American Cyanamid, 1986); azinphos-methyl, 40 (calculated from an equation by Kenaga and Goring, 1978; as cited in Lyman et al., 1982); diflubenzuron, 100 (USDA, 1989); and methyl parathion, 87 (Environmental Fate Database, 1990).

The dietary ingestion exposure resulting from the consumption of contaminated food was then calculated with the following equation:

> Dietary ingestion exposure (mg) = PFC × {Σ[consumption of diet item (g) × residue on diet item (ppm) × $10^{-3}$]}.

Exposure estimates for the consumption of contaminated water were based on the insecticide concentrations in pond water that had received drift residues from a distance of 25 feet, as described above. As with the dietary ingestion exposure, the amount of contaminated water that an animal consumes was assumed to be inversely proportional to its body weight, and the formula used to calculate the percentage of contaminated food was also used to calculate the percentage of water contaminated (PWC). The following equation was then used to calculate the typical oral exposure from water consumption:

> Water consumption exposure (mg) = PWC × [water ingestion (L) × insecticide concentration in water (ppm)]

The final component of the oral dose, grooming exposure, was calculated with the following equation:

> Grooming exposure (mg) = PBG × [DDE (mg) + IND (mg)]

The typical ingestion dose was then calculated by adding the various individual oral doses:

> Typical ingestion dose (mg/kg) = [grooming exposure (mg) + dietary exposure (mg) + water consumption exposure (mg)]/BWT (kg)

### Inhalation Exposures

Wildlife inhalation exposures were assumed to result from the inhalation of insecticide spray droplets of respirable size (30 microns in diameter or less) as those droplets drift offsite. The drift cloud was assumed to disperse within the first 10 m above ground level on a 12.1-hectare (30-acre) site that is 348.4 m on a side. The drift cloud was assumed to consist of respirable droplets that constitute 10 percent of the total applied insecticide by volume. Based on these assumptions, the airborne concentration was 0.00112 mg/L for each 1.12 kg/ha (1 lb/acre) applied. The drift cloud was assumed to move offsite at 0.9 m/second (2 mph), which would expose animals on the downwind edge for 6.5 minutes. Also, the breathing rate of each animal in liters per minute (LPM) was based on the following equations:

$$\text{Birds:}\quad LPM = \frac{284 \times [BWT(g)/1{,}000]^{0.77}}{1{,}000}$$

$$\text{Mammals:}\quad LPM = \frac{379 \times [BWT(g)/1{,}000]^{0.80}}{1{,}000}$$

Reptiles: LPM = 0.00334

Amphibians: LPM = 0.007

The equations for birds and mammals were taken from Lasiewski and Calder (1971). The reptile breathing rate was obtained from a Gordon et al. (1968) study on the collared lizard, and the breathing rate for amphibians was obtained from Hutchinson et al. (1968). The typical inhalation dose for animals was then calculated using the following equation:

Typical inhalation dose (mg/kg) = [airborne concentration (mg/L) × LPM (L/min) × 6.5 minutes]/BWT (kg)

### Total Typical Dose

The dermal, oral, and inhalation doses were added to obtain the total typical dose:

Total typical dose = typical dermal + typical oral + typical inhalation

Typical doses for terrestrial wildlife species are summarized in tables B7-1 through B7-4.

## Exposure Calculations—Extreme Dose Description

### Dermal Exposures

The extreme dermal dose incorporates different assumptions into the same basic equations used in estimating the typical dermal dose. The animal was assumed to receive its direct dermal dose from a direct spray at the full application rate. Accordingly, the following equation was used to calculate the extreme dermal dose:

$$DDE\ (mg) = \text{application rate}\ (mg/cm^2) \times BSA\ (cm^2)$$

It was further assumed that the animal subsequently touched vegetation that also had been directly sprayed with insecticide, causing a higher indirect dermal exposure. The level of insecticide residues on vegetation after direct spraying was based on a leaf area index of 4 and a uniform distribution of the insecticide over the leaf surface. The

equation for the extreme dermal dose was otherwise the same as that for the typical dermal dose.

For honey bees, extreme case dermal exposures were calculated by assuming that insects absorb all of the insecticide residues on their bodies. The insecticide residues on honey bees were assumed to be a fraction of the residues found on forage, with 4.71 ppm for each pound of insecticide applied per acre.

### Ingestion Exposures

For calculating the extreme ingestion dose, 100 percent of an animal's diet items was assumed to be contaminated. Also, the animal's water supply was assumed to have been directly sprayed, which increased the water concentrations used to calculate residues in fish to 0.215 mg/L for malathion, 0.0460 mg/L for azinphos-methyl, 0.0230 mg/L for diflubenzuron, and 0.0920 mg/L for methyl parathion. Residues for onsite diet items were assumed to be the following, based on the study by Hoerger and Kenaga (1972) for a 1-lb/acre application rate:

| Diet item | Residue (ppm/lb/acre) |
|---|---|
| Grass | 92 |
| Forage | 33 |
| Seeds | 3.1 |
| Insects | 4.7 |
| Berries | 1.6 |

Accordingly, the equation for dietary ingestion exposure (mg) was modified as follows:

$$\text{Dietary ingestion exposure (mg)} = \sum [\text{consumption of diet item (g)} \times \text{residue on diet item (ppm)} \times 10^{-3}]$$

Exposure estimates for the consumption of contaminated water were based on the concentrations of insecticide in a pond that had received a direct spray of the insecticide. Otherwise, the assumptions for water consumption exposure in the extreme case were the same as the assumptions used in the typical case. The extreme case residue concentrations in water are listed above.

The equation for the grooming exposure was the same as that used in the typical case; however, the animals were assumed to have been directly sprayed.

### Inhalation Exposures

The extreme inhalation exposures were calculated in the same manner as the typical exposures, except that the wind speed was assumed to be slower, causing a longer period of exposure to the insecticide cloud. The wind speed was assumed to be 0.225 m/second (0.5 mph), which would expose downwind animals for 25.8 minutes. The following is the equation for the extreme inhalation dose:

> Extreme inhalation dose (mg/kg) = [airborne concentration (mg/L) × LPM (L/min) × 25.8 minutes]/BWT (kg)

### Total Extreme Dose

The total extreme dose is the sum of the extreme dermal, ingestion, and inhalation doses:

> Total extreme dose (mg/kg) = extreme dermal + extreme ingestion + extreme inhalation

Extreme doses for terrestrial wildlife species are presented in tables B7-1 through B7-4.

## Aquatic Species

Representative aquatic species typically found in the Cotton Belt regions of the United States were used to estimate risks to nontarget aquatic organisms. The analysis assumed that the aquatic organisms were exposed to insecticide residues by immersion in water bodies that had received varying levels of insecticide through runoff, drift, or direct spraying.

For each aquatic habitat, the total concentration of each insecticide in water, or the estimated environmental concentration (EEC), was calculated by adding estimated runoff concentrations to drift concentrations. The maximum runoff concentrations possible in the habitats were also calculated. Two quantitative models, Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) and Exposure Analysis Modeling System II (EXAMS II), were used to estimate runoff concentrations; and a third model, the Agricultural Dispersal model (AGDISP), was used to estimate drift concentrations from aerial insecticide applications.

The GLEAMS model is appropriate for small rivers or streams and uses precise hydrology and application data, including precipitation runoff, last spray date, and storm date, to estimate runoff concentrations of insecticides. Water bodies representative of the small rivers or streams that occur in various regions of the Cotton Belt were selected for the GLEAMS model. These water bodies, listed by region, are as follows: Neal's Creek (North Carolina), Southeast—Coastal; Pearl River (Mississippi), Southeast—Delta; Leon Creek (Texas), South Central; and Aravaipa Creek (Arizona), Southwest. The GLEAMS output for the representative rivers was assumed to be a reasonable approximation of

the insecticide runoff in water bodies of similar size and geographic location.

Because the EXAMS model is most accurate for moderate to large rivers, it was used to calculate runoff concentrations in large-river aquatic habitats. Thus, five large rivers in the Cotton Belt were modeled: the Tennessee River in Alabama and Tennessee, the Gila River in Arizona, the Red River in Texas and Oklahoma, the Sunflower River in Mississippi, and the Flint River in Georgia. As with GLEAMS, the EXAMS results for these rivers were used not only for species that actually exist in them but also for species living in similar rivers that could not be modeled in the analysis.

The results of both the EXAMS and GLEAMS models were then added to AGDISP drift estimates to produce a final EEC for each aquatic species. See chapter 4 for a description of the EXAMS and GLEAMS models, and see section B8 of this appendix for a description of the AGDISP model.

In addition to the GLEAMS and EXAMS models, a pond model was used to determine insecticide concentrations in small water bodies such as farm ponds. The assumptions used in the pond model are detailed below.

**Exposure Calculations—Typical Case**

In the typical scenario, EECs for each insecticide were calculated from the runoff and drift concentrations of insecticide produced on a watershed basis. As described above, four representative large rivers and four representative small rivers or streams were modeled in the analysis, one for each major region of the Cotton Belt.

In the GLEAMS model, the runoff component of the typical EEC was calculated as an 18-hour weighted average of the total insecticide concentration in the representative watershed divided by the total baseflow in the watershed plus the storm flow. The quantity of aerial spray drift over the entire watershed was then added to the runoff component to determine the final typical EEC. The watershed area upstream from known aquatic species habitat and the baseflow for the river or stream segment comprising the habitat, as determined from the U.S. Geological Survey Water Data Report for each State, were used in the calculations. The total mass of insecticide in the representative watershed was based on the total cotton acreage in the watershed, which was calculated by assuming that the percentage of land devoted to cotton is evenly distributed over each county included in the watershed. The total number of a county's cotton acres in the watershed of concern was calculated from an estimate of the percentage of each county lying within the watershed. After the total number of cotton acres in the watershed of concern was calculated for each county, the ratio of the total cotton acreage in a watershed to the total area of the watershed was calculated, and this percentage was used in the model. It was assumed that 100 percent of the cotton in any watershed may be treated in one workday.

In the EXAMS model, the runoff output from the model was added to the watershed drift estimates to calculate the typical EEC. For the pond modeling, four different scenarios were used to calculate concentrations of insecticides in a circular pond 1 acre in area and 2 feet in depth. The total runoff to the pond included drainage from 30 acres of cotton field, drainage from 3 acres of additional area (access roads, buffer areas, etc.), and the precipitation falling on the pond surface. The runoff calculations were based on a Decatur silt loam soil, which has a high potential for runoff. In addition, the following assumptions were used to calculate the insecticide concentrations in each scenario:

Drift Scenario: Drift concentrations were calculated assuming a buffer of 25 feet between the edge of the field and the edge of the pond. A wind speed of 10 mph was assumed to cause drift on the pond over one-half of its circumference. The area under the drift deposition curve between the two shorelines of the pond was used to determine the total drift per meter of shoreline.

Average Runoff Scenario: Average runoff concentrations were computed by assuming that a large storm occurs 2 days after an insecticide application. Because data for storms of varying length and intensity were available, the storm that gave the maximum insecticide concentration in the GLEAMS output was chosen. A total area of 34 acres contributed runoff to the pond: 30 acres of treated cotton fields, 3 acres of additional land, and the pond itself.

Extreme Runoff Scenario: Extreme runoff concentrations were computed by assuming that a small storm occurs on the same day that a cotton field has been treated. This storm is not large enough to produce runoff, but it is large enough to dislodge the insecticide from the foliage. The next day, the fields are retreated, and a large storm occurs 1 day later. The storm is assumed to be of equivalent magnitude to the storm used in the average runoff scenario. A total area of 34 acres again contributed runoff to the pond, including 30 acres of treated cotton fields, 3 acres of additional land, and the pond itself.

Pond Surface Spray Scenario: Spray concentrations were calculated by assuming that a spray plane applies a single swath of insecticide to a farm pond. It is further assumed that all insecticide from the swath lands on the pond surface.

To determine the typical exposure for the pond scenario, the second highest concentration from the drift, average runoff, and extreme runoff scenarios was assumed to represent the typical pond EEC. Because the average runoff scenario produced the second highest concentration for all insecticides, it in effect represented the typical case. The pond surface spray scenario was not included in the final assessment of risk because this scenario represents a worst case, accidental situation that should be prevented by proper operational procedures.

## Exposure Calculations—Extreme Case

In the extreme case, EECs for each insecticide were calculated from the runoff concentrations that would drain from cotton fields located directly upgradient from an aquatic species' habitat and the drift concentrations that would result if drift residues landed directly on the river or stream of concern. In the GLEAMS model, the extreme EEC was calculated from the 18-hour weighted average of total insecticide in the watershed plus a "plug" of river or stream water containing the drift concentration. For the EXAMS model, the runoff output from the model was added to the "plug" concentration of drift to derive the total extreme EEC.

A concern exists whenever program operations require that aircraft fly near rivers or streams. Professional pilots and ground observers are used to avoid impacts to all sensitive areas. Whenever special protection is required for a species' habitat, pilots will fly parallel to the body of water, thereby avoiding the need to turn the aircraft over the water after each pass through the field. Where treatment areas are separated from airports by long expanses of protected rivers or streams, ferrying flights (overflights) will take the most direct route across the river or stream. In most cases, this will mean the flight path will be perpendicular to the stream or river channel. A typical aircraft traveling at 115 mph (169 feet per second) will require less than 2 seconds to cross most streams and waterways in cotton production areas. It is extremely unlikely that an aircraft would crash or an insecticide would be jettisoned during overflight of a river or stream.

In the pond modeling, the highest concentration from the drift, average runoff, and extreme runoff scenarios was assumed to represent the extreme EEC. Because the extreme runoff scenario produced the highest concentration for all insecticides, it in effect represented the extreme case.

The EECs for ponds, streams or small rivers, and large rivers are presented by chemical in the following tables: tables B7-5 through B7-14 for malathion; tables B7-15 through B7-24 for azinphos-methyl; tables B7-25 through B7-34 for diflubenzuron; and tables B7-35 through B7-44 for methyl parathion.

# Section B7

# Nontarget Species Risk Analysis

This section considers the potential effects of malathion, azinphos-methyl, diflubenzuron, and methyl parathion on nontarget wildlife and aquatic species in the National Boll Weevil Cooperative Control Program. Risks to wildlife and aquatic species from insecticides used for boll weevil control are directly related to the inherent toxicity (or hazard) of each insecticide to organisms and to the amount of each chemical (or dose) received by those organisms from boll weevil control operations. The nontarget wildlife and aquatic species risk analysis compares estimated acute exposures of representative species with the acute toxicity levels found in laboratory studies.

## Wildlife Risk Analysis

The criteria that EPA (1986) uses in its ecological risk assessment of nontarget species were used to determine the risks to the different representative wildlife species and the relative risks from the four insecticides. The EPA criteria call for a comparison of the estimated dose received by an animal to the laboratory-determined $LD_{50}$ for the most closely related laboratory test species.

For nonendangered terrestrial wildlife species, EPA (1986) assesses the risk of chemical exposure according to the following scale:

Low — Expected Dose < 1/5 $LD_{50}$
Moderate — 1/5 $LD_{50} \leq$ Expected Dose < $LD_{50}$
High — Expected Dose $\geq LD_{50}$

Doses below the 1/5 $LD_{50}$ level are assumed to present a low or negligible risk, doses between the 1/5 $LD_{50}$ level and the $LD_{50}$ are assumed to present a moderate risk that may be mitigated by restricted insecticide use, and doses above the $LD_{50}$ are assumed to present an unacceptably high risk.

### Toxicity Surrogates

In this wildlife risk assessment, representative species for wildlife commonly found in the program regions were identified, and the doses they could receive from exposure to the four insecticides were calculated. In some cases, however, information was not available on toxic doses to these species. Therefore, it was necessary to select a closely related species that had available toxicity data. For example, the belted kingfisher was selected as a common fish-eating bird in the Cotton Belt, but no toxicity data were available. The mallard duck was then identified as closely related, and toxicity data for the duck were used in the risk calculations.

**Surrogates for Avian and Mammalian Toxicity**

Toxicity data on the most closely related avian or mammalian species were used for the wildlife species risk comparisons. For avian species, mallard duck data were used only when data on an upland species, such as the Japanese quail or pheasant, were not available. If a mammalian wildlife species (for example, red fox) had no data available, data on laboratory mammals (such as rats, mice, or dogs) were used.

**Surrogates for Amphibian and Reptile Toxicity**

During the testing of almost 200 chemicals on terrestrial vertebrate wildlife species, the Fish and Wildlife Service studied the effects of 17 pesticides on the adult bullfrog and the mallard duck. There was a positive correlation ($r = 0.67$) between the $LD_{50}$s for the bullfrog and mallard for the tested chemicals. The bullfrog $LD_{50}$s were higher in 12 of the 17 cases, often by more than an order of magnitude, allowing for a reasonable and conservative (unlikely to underestimate risks) use of the mallard data to estimate risk to amphibians (Hudson et al., 1984).

The Fish and Wildlife Service also reviewed the available toxicity data of environmental contaminants to reptiles. Most of the data consisted of residue levels of organochlorides in reptiles after field applications. There were no data such as that reported in the above amphibian studies that related dose levels to lethality; however, the author noted that although reptiles seem to be more susceptible to pesticides than birds or mammals, avian data could serve as a guide for reptile toxicity because birds and reptiles are closely related (Hall, 1980).

Thus, for the four boll weevil program insecticides, no suitable data exist for the terrestrial stages of amphibians or for reptiles. Because there is a reasonable correlation between avian and amphibian toxicity, as indicated in the mallard and bullfrog $LD_{50}$ analysis, and because a similar relationship between avian and reptilian toxicity may exist, available avian toxicity data were used as surrogate data for both amphibians and reptiles.

**Wildlife Risk Overview**

The potential risks to nontarget wildlife species are presented in tables B7-1 through B7-4 at the end of this section. Each table shows the total typical and extreme dose estimates for each representative wildlife species. The $LD_{50}$ values for the indicator species and the subsequent 1/5 of the $LD_{50}$ values also are provided.

### Malathion

In the typical scenario, drift residues of malathion pose a low risk to terrestrial wildlife; none of the typical scenario dose estimates exceeded the 1/5 $LD_{50}$ values for wildlife. In the extreme case, the insecticide poses a moderate risk to honey bees that are directly sprayed. If honey bees are present in a cotton field during spraying operations, they may be killed.

### Azinphos-methyl

Drift residues of azinphos-methyl pose a low risk to terrestrial representative species. A direct spray of azinphos-methyl during an extreme scenario poses a moderate risk to the eastern cottontail, desert cottontail, red fox, coyote, cotton mouse, deer mouse, and honey bee. A direct spray could also pose a high risk to the eastern and western kingbirds, eastern garter snake, western diamondback rattlesnake, Fowler's toad, Rocky Mountain toad, and red-spotted toad.

### Diflubenzuron

In both the typical and extreme cases, diflubenzuron exposure estimates were less than the 1/5 $LD_{50}$ values for terrestrial wildlife. Therefore, the insecticide presents a low risk to wildlife.

### Methyl Parathion

Drift residues of methyl parathion present a moderate risk to the eastern and western kingbirds, American kestrel, eastern garter snake, western diamondback rattlesnake, Fowler's toad, Rocky Mountain toad, red-spotted toad, and honey bee. A direct spray of the insecticide could cause a moderate risk of toxicity to the northern bobwhite, Gambel's quail, white-tailed deer, and mule deer. Direct spraying also poses a moderate risk to two domestic animals—cow and chicken. Direct spray of methyl parathion causes a high risk to the eastern and western kingbirds, American kestrel, belted kingfisher, cotton mouse, deer mouse, eastern garter snake, western diamondback rattlesnake, Fowler's toad, Rocky Mountain toad, red-spotted toad, and honey bee.

## Aquatic Species Risk Analysis

To estimate the susceptibility of nonendangered aquatic species to the program insecticides, representative aquatic species in the Cotton Belt were selected. These species also had acute toxicity reference values (median lethal concentration or median environmental concentration ($LC_{50}$ or $EC_{50}$)), determined in laboratory studies. The toxicity reference values were then compared with the expected environmental concentrations (EECs) and the maximum runoff concentrations of each insecticide. The criteria of EPA (1986) for ecological risk assessment were used to assess the possible effects of chemical exposure on the aquatic species. EPA (1986) prescribes the following risk categories for aquatic organisms:

Low — $EEC < 1/10\ LC_{50}$
Moderate — $1/10\ LC_{50} \leq EEC < 1/2\ LC_{50}$
High — $EEC \geq 1/2\ LC_{50}$

Doses below the 1/10 $LC_{50}$ level are assumed to present a low or negligible risk, doses between the 1/10 $LC_{50}$ level and the 1/2 $LC_{50}$ value are assumed to present a moderate risk that may be mitigated by restricted pesticide use, and doses above the 1/2 $LC_{50}$ level are assumed to present an unacceptably high risk.

The typical and extreme EECs were also compared to 96-hour $LC_{50}$s because the EECs may persist for as long as 2 days in water. No toxicity surrogates were necessary because aquatic species that commonly occur in the Cotton Belt had available toxicity data and were selected for the risk assessment.

**Aquatic Risk Overview**

The calculated risks to nonendangered aquatic species are presented in tables B7-5 through B7-44 at the end of this section. These tables are grouped by chemical. Risks posed to aquatic species in ponds, streams, and small and large rivers are analyzed for each chemical. Tables B7-5 through B7-14 list risks associated with the use of malathion; tables B7-15 through B7-24 list risks associated with the use of azinphos-methyl; tables B7-25 through B7-34 list risks associated with the use of diflubenzuron; and tables B7-35 through B7-44 list risks associated with the use of methyl parathion. These tables show the EECs for each type of water body as well as the $LC_{50}$ and 1/10 $LC_{50}$ values for each chemical, which together provide the basis for the risk designation using the criteria of EPA (1986).

### Malathion

In ponds, average runoff concentrations of malathion (typical scenario) present a moderate risk to green sunfish, largemouth bass, yellow perch, Fowler's toad tadpoles, and western chorus frog tadpoles. Malathion concentrations from runoff present a high risk to bluegills, daphnia, scuds, grass shrimp, and stoneflies. Runoff concentrations of malathion (extreme scenario) in ponds present a moderate risk to Fowler's toad tadpoles and a high risk to bluegills, green sunfish, largemouth bass, yellow perch, daphnia, scuds, grass shrimp, stoneflies, and western chorus frog tadpoles.

In a model of Neal's Creek (Southeast-Coastal), watershed concentrations of malathion (typical scenario) present a high risk to aquatic invertebrates, such as daphnia, scuds, and stoneflies. A "plug" concentration of malathion (extreme scenario) presents a moderate risk to bluegills and grass shrimp and a high risk to daphnia, scuds, and stoneflies. Similarly, typical scenario concentrations of malathion in the Pearl River (Southeast-Delta) present a moderate risk to bluegills and a high risk to daphnia, scuds, and stoneflies. Extreme case concentrations of malathion present a moderate risk to bluegills and grass shrimp and a high risk to daphnia, scuds, and stoneflies. In a model of Leon Creek (South Central), both typical and extreme concentrations of malathion present a high risk to daphnia, scuds, and stoneflies. In Aravaipa Creek (Southwest), both the typical and extreme malathion levels present a high risk to daphnia, scuds, and stoneflies. The extreme concentration of malathion in Aravaipa Creek also presents a moderate risk to bluegills and grass shrimp.

According to the EXAMS model data, the concentration of malathion in the Tennessee River from an eradication program could present a moderate risk to daphnia, scuds, and stoneflies. The concentration of

malathion in the Tennessee River from a suppression program could present a moderate risk to daphnia and stoneflies and a high risk to scuds. In a model of the Flint River, both the eradication and suppression program concentrations of malathion could present a high risk to daphnia, scuds, and stoneflies. In a model of the Sunflower River, malathion concentrations expected from an eradication program could present a moderate risk to green sunfish, largemouth bass, yellow perch, and western chorus frog tadpoles and a high risk to bluegills, daphnia, scuds, grass shrimp, and stoneflies. Suppression program concentrations of malathion in the Sunflower River could likely present a moderate risk to green sunfish, yellow perch, and western chorus frog tadpoles and a high risk to bluegills, daphnia, scuds, grass shrimp, and stoneflies. In a model of the Red River, both the eradication and suppression concentrations of malathion could produce a moderate risk to largemouth bass, yellow perch, and Fowler's toad tadpoles and a high risk to bluegills, green sunfish, daphnia, scuds, grass shrimp, stoneflies, and western chorus frog tadpoles. In a model of the Gila River, concentrations of malathion expected from an eradication program could present a moderate risk to bluegills and grass shrimp and a high risk to daphnia, scuds, and stoneflies. Suppression program concentrations of malathion in the Gila River could produce a moderate risk to bluegills and a high risk to daphnia, scuds, and stoneflies.

### Azinphos-methyl

Average azinphos-methyl runoff concentrations in models of ponds produce a moderate risk to green sunfish, crayfish, and Fowler's toad tadpoles and a high risk to bluegills, largemouth bass, yellow perch, aquatic sowbugs, scuds, and stoneflies. Extreme azinphos-methyl runoff concentrations in pond models present a moderate risk to fathead minnows and a high risk to bluegills, green sunfish, largemouth bass, yellow perch, aquatic sowbugs, scuds, crayfish, stoneflies, and Fowler's toad.

Typical scenario concentrations of azinphos-methyl in a model of Neal's Creek present a moderate risk to bluegills, yellow perch, and stoneflies and a high risk to scuds. The extreme concentration of azinphos-methyl produces a moderate risk to bluegills and largemouth bass and a high risk to yellow perch, scuds, and stoneflies. In a model of the Pearl River, both the typical and extreme azinphos-methyl levels pose a moderate risk to bluegills and largemouth bass and a high risk to yellow perch, scuds, and stoneflies. In a model of Leon Creek, both the typical and extreme concentrations of azinphos-methyl present a moderate risk to bluegills, largemouth bass, yellow perch, and stoneflies and a high risk to scuds. In a model of Aravaipa Creek, the typical and extreme azinphos-methyl scenario concentrations present a moderate risk to bluegills and largemouth bass and a high risk to scuds. In addition, an azinphos-methyl concentration in Aravaipa Creek produces a moderate risk to yellow perch and stoneflies in the typical scenario and a high risk in the extreme scenario.

Based on EXAMS model data, azinphos-methyl levels in the Tennessee River expected from both an eradication program and a suppression program could present a high risk to scuds. In the Flint River, eradication program concentrations of azinphos-methyl could present a moderate risk to bluegills, yellow perch, and stoneflies and a high risk to scuds. Suppression program concentrations of azinphos-methyl in the Flint River pose a moderate risk to yellow perch and stoneflies and a high risk to scuds. In a model of the Sunflower River, concentrations of azinphos-methyl from both the eradication and suppression programs could present a moderate risk to green sunfish, aquatic sowbugs, and crayfish and a high risk to bluegills, largemouth bass, yellow perch, scuds, and stoneflies. In a model of the Red River, concentrations of azinphos-methyl from both eradication and suppression programs could produce a moderate risk to fathead minnows, crayfish, and Fowler's toad tadpoles and a high risk to bluegills, largemouth bass, yellow perch, aquatic sowbugs, scuds, and stoneflies. Also, Red River concentrations of azinphos-methyl could present a moderate risk to green sunfish during an eradication program and a high risk during a suppression program. In a model of the Gila River, azinphos-methyl concentrations from an eradication program could present a moderate risk to aquatic sowbugs and a high risk to bluegills, largemouth bass, yellow perch, scuds, and stoneflies. In a suppression program, concentrations of azinphos-methyl in the Gila River present a moderate risk to bluegills and largemouth bass and a high risk to yellow perch, scuds, and stoneflies.

### Diflubenzuron

In ponds, both the typical and extreme scenario runoff concentrations of diflubenzuron could present a moderate risk to scuds and a high risk to daphnia. A "plug" concentration of diflubenzuron (extreme case) presents a moderate risk to daphnia in Aravaipa Creek and a high risk to daphnia in Neal's Creek. Neither the typical nor the extreme scenario concentrations of diflubenzuron present unacceptable risks to any aquatic species in the Pearl River or Leon Creek.

Diflubenzuron does not present an unacceptable risk to any aquatic species in the Tennessee or Flint Rivers. In a model of the Sunflower River, concentrations of diflubenzuron from an eradication program could present a moderate risk to scuds and a high risk to daphnia. Diflubenzuron presents a high risk to daphnia and scuds in the Red River and a high risk to daphnia in the Gila River. Diflubenzuron also presents a moderate risk to scuds in the Gila River. Because diflubenzuron is not used for suppression, no suppression concentrations were estimated with the EXAMS program.

### Methyl Parathion

Typical scenario runoff concentrations of methyl parathion in ponds present a moderate risk to damselflies, a high risk to crayfish, and a high risk to both daphnia species (based on testing in *Daphnia magna*

and *Simocephalus serrulatus*). Extreme scenario runoff concentrations of methyl parathion in ponds could present a high risk to daphnia (*D. magna* and *S. serrulatus*), damselflies, and crayfish.

Typical scenario concentrations of methyl parathion in Neal's Creek could present a moderate risk to crayfish and a high risk to daphnia (*D. magna* and *S. serrulatus*). Extreme concentrations of methyl parathion in Neal's Creek could present a high risk to crayfish and the two daphnia species. In a model of the Pearl River, both the typical and extreme scenario concentrations present a moderate risk to crayfish and a high risk to *D. magna* and *S. serrulatus*. In a model of Leon Creek, the typical and extreme concentrations present a moderate risk to *S. serrulatus* and a high risk to *D. magna*. In Aravaipa Creek, the typical scenario concentrations of methyl parathion could present a moderate risk to crayfish and a high risk to *D. magna* and *S. serrulatus*, while the extreme scenario concentrations present a high risk to crayfish and the two daphnia species.

In a model of the Tennessee River, concentrations of methyl parathion from an eradication program could present a moderate risk to *D. magna* and *S. serrulatus*. In a suppression program, concentrations of methyl parathion in the Tennessee River could produce a moderate risk to *S. serrulatus* and a high risk to *D. magna*. In a model of the Flint River, concentrations of methyl parathion from both an eradication and suppression program could present a high risk to *D. magna* and *S. serrulatus*. In a model of the Sunflower River, concentrations of methyl parathion from an eradication program could present a moderate risk to crayfish and a high risk to *D. magna* and *S. serrulatus*, while a suppression program could present a moderate risk to damselflies and a high risk to crayfish, *D. magna*, and *S. serrulatus*. In a model of the Red River, concentrations of methyl parathion from either an eradication program or a suppression program could produce a high risk to crayfish, *D. magna*, and *S. serrulatus*. Similarly, *D. magna* and *S. serrulatus* in the Gila River face a high risk during the eradication or suppression programs.

## Conclusion

Malathion poses little risk to most terrestrial organisms but may pose a high risk to fish, amphibians, and aquatic invertebrates. Drift concentrations of azinphos-methyl present little risk to terrestrial organisms, but a direct spray of this insecticide may present moderate to high risks. For aquatic species, azinphos-methyl presents a high risk to fish, amphibians, and aquatic invertebrates. Drift concentrations of methyl parathion may present a moderate risk to some terrestrial species, while a direct spray presents moderate to high risks. Also, methyl parathion poses moderate to high risk to aquatic invertebrates. Diflubenzuron presents little risk to terrestrial organisms but may pose a moderate to high risk to aquatic invertebrates.

**Table B7-1. Risk to Wildlife Species From Malathion**

| Species and program area | Typical dose estimate (mg/kg) | Extreme dose estimate (mg/kg) | 1/5 $LD_{50}$ (mg/kg) | $LD_{50}$ (mg/kg) | Indicator species |
|---|---|---|---|---|---|
| **Birds:** | | | | | |
| Eastern kingbird (*Tyrannus tyrannus*) (E,C)[a] | 5.15 | 45.8 | 80 | 400 | Bobwhite |
| Western kingbird (*Tyrannus verticalis*) (W) | 5.15 | 45.8 | 80 | 400 | Bobwhite |
| Northern bobwhite (*Colinus virginianus*) (E,C) | 1.83 | 16.7 | 80 | 400 | Bobwhite |
| Gambel's quail (*Callipepla gambelii*) (W) | 1.83 | 16.7 | 80 | 400 | Bobwhite |
| American kestrel (*Falco sparverius*) (E,C,W) | 2.95 | 37.1 | 80 | 400 | Bobwhite |
| Belted kingfisher (*Megaceryle alcyon*) (E,C,W) | 1.71 | 13.9 | 297 | 1,485 | Mallard |
| **Mammals:** | | | | | |
| Eastern cottontail (*Sylvilagus floridanus*) (E,C) | 0.820 | 13.9 | 50 | 250 | Rabbit |
| Desert cottontail (*Sylvilagus auduboni*) (W) | 0.820 | 13.9 | 50 | 250 | Rabbit |
| Cotton mouse (*Peromyscus gossypinus*) (E) | 7.63 | 67.4 | 101 | 507 | Mouse |
| Deer mouse (*Peromyscus maniculatus*) (C,W) | 7.63 | 67.4 | 101 | 507 | Mouse |
| White-tailed deer (*Odocoileus virginianus*) (E,C) | 0.0975 | 2.57 | 10.6 | 53 | Cattle |
| Mule deer (*Odocoileus hemionus*) (W) | 0.0975 | 2.57 | 10.6 | 53 | Cattle |
| Red fox (*Vulpes fulva*) (E) | 0.337 | 5.93 | 275 | 1,375 | Rat |
| Coyote (*Canis latrans*) (C,W) | 0.202 | 4.23 | 275 | 1,375 | Rat |
| **Reptiles:** | | | | | |
| Eastern garter snake (*Thamnophis sirtalis sirtalis*) (E) | 2.50 | 41.9 | 80 | 400 | Bobwhite |
| Western diamondback rattlesnake (*Crotalus atrox*) (C,W) | 2.50 | 41.9 | 80 | 400 | Bobwhite |
| **Amphibians:** | | | | | |
| Fowler's toad (*Bufo woodhousei fowleri*) (E) | 3.26 | 28.3 | 80 | 400 | Bobwhite |
| Rocky Mountain toad (*Bufo woodhousei woodhousei*) (C) | 3.26 | 28.3 | 80 | 400 | Bobwhite |
| Red-spotted toad (*Bufo punctatus*) (W) | 3.26 | 28.3 | 80 | 400 | Bobwhite |
| **Insect:** | | | | | |
| Honey bee (*Apis mellifera*) (E,C,W) | 0.627 | 5.50 | 1.182 | 5.908 | Honey bee |
| **Domestic animals:** | | | | | |
| Cow | 0.0561 | 3.14 | 10.6 | 53 | Cow |
| Chicken | 0.414 | 4.06 | 30 | 150 | Chicken |
| Dog | 0.165 | 1.44 | 275 | 1,375 | Rat |

[a] E = Southeast, C = South Central, W = Southwest.

**Table B7-2. Risk to Wildlife Species From Azinphos-methyl**

| Species and program area | Typical dose estimate (mg/kg) | Extreme dose estimate (mg/kg) | 1/5 $LD_{50}$ (mg/kg) | $LD_{50}$ (mg/kg) | Indicator species |
|---|---|---|---|---|---|
| **Birds:** | | | | | |
| Eastern kingbird (*Tyrannus tyrannus*) (E,C)[a] | 1.14 | 10.1 | 1.6 | 8.0 | Red-winged blackbird |
| Western kingbird (*Tyrannus verticalis*) (W) | 1.14 | 10.1 | 1.6 | 8.0 | Red-winged blackbird |
| Northern bobwhite (*Colinus virginianus*) (E,C) | 0.425 | 3.86 | 12 | 60 | Bobwhite |
| Gambel's quail (*Callipepla gambelii*) (W) | 0.425 | 3.86 | 12 | 60 | Bobwhite |
| American kestrel (*Falco sparverius*) (E,C,W) | 0.672 | 8.36 | 12 | 60 | Bobwhite |
| Belted kingfisher (*Megaceryle alcyon*) (E,C,W) | 0.402 | 3.27 | 27.2 | 136 | Mallard |
| **Mammals:** | | | | | |
| Eastern cottontail (*Sylvilagus floridanus*) (E,C) | 0.204 | 3.22 | 0.88 | 4.4 | Rat |
| Desert cottontail (*Sylvilagus audubonii*) (W) | 0.204 | 3.22 | 0.88 | 4.4 | Rat |
| Cotton mouse (*Peromyscus gossypinus*) (E) | 1.69 | 14.9 | 3 | 15 | Mouse |
| Deer mouse (*Peromyscus maniculatus*) (C,W) | 1.69 | 14.9 | 3 | 15 | Mouse |
| White-tailed deer (*Odocoileus virginianus*) (E,C) | 0.0289 | 0.621 | 6.4 | 32 | Mule deer |
| Mule deer (*Odocoileus hemionus*) (W) | 0.0289 | 0.621 | 6.4 | 32 | Mule deer |
| Red fox (*Vulpes fulva*) (E) | 0.0912 | 1.46 | 0.88 | 4.4 | Rat |
| Coyote (*Canis latrans*) (C,W) | 0.0568 | 1.04 | 0.88 | 4.4 | Rat |
| **Reptiles:** | | | | | |
| Eastern garter snake (*Thamnophis sirtalis sirtalis*) (E) | 0.642 | 10.0 | 1.6 | 8.0 | Red-winged blackbird |
| Western diamondback rattlesnake (*Crotalus atrox*) (C,W) | 0.642 | 10.0 | 1.6 | 8.0 | Red-winged blackbird |
| **Amphibians:** | | | | | |
| Fowler's toad (*Bufo woodhousei fowleri*) (E) | 1.30 | 11.4 | 1.6 | 8.0 | Red-winged blackbird |
| Rocky Mountain toad (*Bufo woodhousei woodhousei*) (C) | 1.30 | 11.4 | 1.6 | 8.0 | Red-winged blackbird |
| Red-spotted toad (*Bufo punctatus*) (W) | 1.30 | 11.4 | 1.6 | 8.0 | Red-winged blackbird |
| **Insect:** | | | | | |
| Honey bee (*Apis mellifera*) (E,C,W) | 0.134 | 1.118 | 0.25 | 1.25 | Honey bee |
| **Domestic animals:** | | | | | |
| Cow | 0.0162 | 0.709 | 6.4 | 32 | Mule deer |
| Chicken | 0.107 | 1.39 | 55.4 | 277 | Chicken |
| Dog | 0.0492 | 0.430 | 0.88 | 4.4 | Rat |

[a] E = Southeast, C = South Central, W = Southwest.

**Table B7-3. Risk to Wildlife Species From Diflubenzuron**

| Species and program area | Typical dose estimate (mg/kg) | Extreme dose estimate (mg/kg) | 1/5 $LD_{50}$ (mg/kg) | $LD_{50}$ (mg/kg) | Indicator species |
|---|---|---|---|---|---|
| **Birds:** | | | | | |
| Eastern kingbird (*Tyrannus tyrannus*) (E,C)[a] | 0.555 | 4.94 | 400 | 2,000 | Mallard |
| Western kingbird (*Tyrannus verticalis*) (W) | 0.555 | 4.94 | 400 | 2,000 | Mallard |
| Northern bobwhite (*Colinus virginianus*) (E,C) | 0.199 | 1.81 | 400 | 2,000 | Mallard |
| Gambel's quail (*Callipepla gambelii*) (W) | 0.199 | 1.81 | 400 | 2,000 | Mallard |
| American kestrel (*Falco sparverius*) (E,C,W) | 0.320 | 4.01 | 400 | 2,000 | Mallard |
| Belted kingfisher (*Megaceryle alcyon*) (E,C,W) | 0.241 | 1.80 | 400 | 2,000 | Mallard |
| **Mammals:** | | | | | |
| Eastern cottontail (*Sylvilagus floridanus*) (E,C) | 0.091 | 1.51 | 928 | 4,640 | Rat |
| Desert cottontail (*Sylvilagus audubonii*) (W) | 0.091 | 1.51 | 928 | 4,640 | Rat |
| Cotton mouse (*Peromyscus gossypinus*) (E) | 0.822 | 7.26 | 928 | 4,640 | Mouse |
| Deer mouse (*Peromyscus maniculatus*) (C,W) | 0.822 | 7.26 | 928 | 4,640 | Mouse |
| White-tailed deer (*Odocoileus virginianus*) (E,C) | 0.0114 | 0.283 | 928 | 4,640 | Rat |
| Mule deer (*Odocoileus hemionus*) (W) | 0.0114 | 0.283 | 928 | 4,640 | Rat |
| Red fox (*Vulpes fulva*) (E) | 0.0382 | 0.656 | 928 | 4,640 | Rat |
| Coyote (*Canis latrans*) (C,W) | 0.0231 | 0.468 | 928 | 4,640 | Rat |
| **Reptiles:** | | | | | |
| Eastern garter snake (*Thamnophis sirtalis sirtalis*) (E) | 0.280 | 4.60 | 400 | 2,000 | Mallard |
| Western diamondback rattlesnake (*Crotalus atrox*) (C,W) | 0.280 | 4.60 | 400 | 2,000 | Mallard |
| **Amphibians:** | | | | | |
| Fowler's toad (*Bufo woodhousei fowleri*) (E) | 0.419 | 3.65 | 400 | 2,000 | Mallard |
| Rocky Mountain toad (*Bufo woodhousei woodhousei*) (C) | 0.419 | 3.65 | 400 | 2,000 | Mallard |
| Red-spotted toad (*Bufo punctatus*) (W) | 0.419 | 3.65 | 400 | 2,000 | Mallard |
| **Insect:** | | | | | |
| Honey bee (*Apis mellifera*) (E,C,W) | 0.067 | 0.589 | 191 | 957 | Honey bee |
| **Domestic animals:** | | | | | |
| Cow | 0.00649 | 0.340 | 928 | 4,640 | Rat |
| Chicken | 0.0464 | 0.453 | 400 | 2,000 | Mallard |
| Dog | 0.0192 | 0.168 | 928 | 4,640 | Rat |

[a] E = Southeast, C = South Central, W = Southwest.

Table B7-4. Risk to Wildlife Species From Methyl Parathion

| Species and program area | Typical dose estimate (mg/kg) | Extreme dose estimate (mg/kg) | 1/5 $LD_{50}$ (mg/kg) | $LD_{50}$ (mg/kg) | Indicator species |
|---|---|---|---|---|---|
| **Birds:** | | | | | |
| Eastern kingbird (*Tyrannus tyrannus*) (E,C)[a] | 2.22 | 19.8 | 2 | 10 | Red-winged blackbird |
| Western kingbird (*Tyrannus verticalis*) (W) | 2.22 | 19.8 | 2 | 10 | Red-winged blackbird |
| Northern bobwhite (*Colinus virginianus*) (E,C) | 0.797 | 7.26 | 1.51 | 7.56 | Bobwhite |
| Gambel's quail (*Callipepla gambelii*) (W) | 0.797 | 7.26 | 1.51 | 7.56 | Bobwhite |
| American kestrel (*Falco sparverius*) (E,C,W) | 1.28 | 16.0 | 0.616 | 3.08 | American kestrel |
| Belted kingfisher (*Megaceryle alcyon*) (E,C,W) | 0.918 | 6.98 | 1.32 | 6.60 | Mallard |
| **Mammals:** | | | | | |
| Eastern cottontail (*Sylvilagus floridanus*) (E,C) | 0.364 | 6.05 | 84 | 420 | Rabbit |
| Desert cottontail (*Sylvilagus audubonii*) (W) | 0.364 | 6.05 | 84 | 420 | Rabbit |
| Cotton mouse (*Peromyscus gossypinus*) (E) | 3.29 | 29.0 | 4.6 | 23 | Mouse |
| Deer mouse (*Peromyscus maniculatus*) (C,W) | 3.29 | 29.0 | 4.6 | 23 | Mouse |
| White-tailed deer (*Odocoileus virginianus*) (E,C) | 0.0455 | 1.13 | 0.72 | 3.6 | Rat |
| Mule deer (*Odocoileus hemionus*) (W) | 0.0455 | 1.13 | 0.72 | 3.6 | Rat |
| Red fox (*Vulpes fulva*) (E) | 0.153 | 2.62 | 18 | 90 | Dog |
| Coyote (*Canis latrans*) (C,W) | 0.0926 | 1.87 | 18 | 90 | Dog |
| **Reptiles:** | | | | | |
| Eastern garter snake (*Thamnophis sirtalis sirtalis*) (E) | 1.12 | 18.4 | 0.616 | 3.08 | American kestrel |
| Western diamondback rattlesnake (*Crotalus atrox*) (C,W) | 1.12 | 18.4 | 0.616 | 3.08 | American kestrel |
| **Amphibians:** | | | | | |
| Fowler's toad (*Bufo woodhousei fowleri*) (E) | 1.68 | 14.6 | 0.616 | 3.08 | American kestrel |
| Rocky Mountain toad (*Bufo woodhousei woodhousei*) (C) | 1.68 | 14.6 | 0.616 | 3.08 | American kestrel |
| Red-spotted toad (*Bufo punctatus*) (W) | 1.68 | 14.6 | 0.616 | 3.08 | American kestrel |
| **Insect:** | | | | | |
| Honey bee (*Apis mellifera*) (E,C,W) | 0.268 | 2.36 | 0.102 | 0.508 | Honey bee |
| **Domestic animals:** | | | | | |
| Cow | 0.0259 | 1.36 | 0.72 | 3.6 | Rat |
| Chicken | 0.185 | 1.81 | 1.51 | 7.56 | Bobwhite |
| Dog | 0.0769 | 0.672 | 18 | 90 | Dog |

[a] E = Southeast, C = South Central, W = Southwest.

**Table B7-5. Acute Risk From Malathion to Aquatic Species in Ponds**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.0455 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | High |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Moderate |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.00 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | High |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Moderate |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Moderate |

**Table B7-5. Acute Risk From Malathion to Aquatic Species in Ponds (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.168 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | High |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | High |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | High |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | High |
| Stonefly (*Pteronarcys californica*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Moderate |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | High |

[a] EEC = Estimated environmental concentration.

Table B7-6. Acute Risk From Malathion to Aquatic Species in Neal's Creek

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.00169 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

**Table B7-6. Acute Risk From Malathion to Aquatic Species in Neal's Creek (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00590 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Moderate |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-7. Acute Risk From Malathion to Aquatic Species in the Pearl River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.00273 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

Table B7-7. Acute Risk From Malathion to Aquatic Species in the Pearl River (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00475 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Moderate |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-8. Acute Risk From Malathion to Aquatic Species in Leon Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC [a] = 0.0015 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

Table B7-8. Acute Risk From Malathion to Aquatic Species in Leon Creek (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.0015 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-9. Acute Risk From Malathion to Aquatic Species in Aravaipa Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.00182 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

**Table B7-9. Acute Risk From Malathion to Aquatic Species in Aravaipa Creek (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00482 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Moderate |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-10. Acute Risk From Malathion to Aquatic Species in the Tennessee River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.000358 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | Moderate |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | Moderate |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

**Table B7-10. Acute Risk From Malathion to Aquatic Species in the Tennessee River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC [a] = 0.0004605 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | Moderate |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-11. Acute Risk From Malathion to Aquatic Species in the Flint River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.001729 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

**Table B7-11. Acute Risk From Malathion to Aquatic Species in the Flint River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.001514 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Low |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-12. Acute Risk From Malathion to Aquatic Species in the Sunflower River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC[a] = 0.02856 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | High |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Moderate |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | High |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Moderate |

**Table B7-12. Acute Risk From Malathion to Aquatic Species in the Sunflower River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.02722 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | High |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Moderate |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.0076 | 0.00076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | High |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Moderate |

[a] EEC = Estimated environmental concentration.

**Table B7-13. Acute Risk From Malathion to Aquatic Species in the Red River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.116 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | High |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | High |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | High |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Moderate |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | High |

**Table B7-13. Acute Risk From Malathion to Aquatic Species in the Red River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC [a] = 0.117 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | High |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | High |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.0076 | 0.00076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | High |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Moderate |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | High |

[a] EEC = Estimated environmental concentration.

**Table B7-14. Acute Risk From Malathion to Aquatic Species in the Gila River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.009206 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Moderate |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

**Table B7-14. Acute Risk From Malathion to Aquatic Species in the Gila River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC [a] = 0.003137 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 11.700 | 1.17 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.020 | 0.002 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 8.970 | 0.897 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.650 | 0.865 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.146 | 0.0146 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.285 | 0.0285 | Low |
| Yellow perch (*Perca flavescens*) | 0.263 | 0.0263 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 3.000 | 0.300 | Low |
| Daphnia (*Daphnia magna*) | 0.001 | 0.0001 | High |
| Scud (*Gammarus fasciatus*) | 0.00076 | 0.000076 | High |
| Grass shrimp (*Paleomonetes kadiakensis*) | 0.032 | 0.0032 | Low |
| Stonefly (*Pteronarcella badia*) | 0.0011 | 0.00011 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.420 | 0.042 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 0.200 | 0.020 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-15. Acute Risk From Azinphos-methyl to Aquatic Species in Ponds**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC [a] = 0.0193 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | High |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Moderate |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | High |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | High |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Moderate |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Moderate |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

Table B7-15. Acute Risk From Azinphos-methyl to Aquatic Species in Ponds (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.0568 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | High |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Moderate |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | High |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | High |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | High |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | High |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | High |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

Table B7-16. Acute Risk From Azinphos-methyl to Aquatic Species in Neal's Creek

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC [a] = 0.000425 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Low |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

Table B7-16. Acute Risk From Azinphos-methyl to Aquatic Species in Neal's Creek (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00132 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.05 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

Table B7-17. Acute Risk From Azinphos-methyl to Aquatic Species in the Pearl River

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.00123 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

Table B7-17. Acute Risk From Azinphos-methyl to Aquatic Species in the Pearl River (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00166 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus* sp.) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.05 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-18. Acute Risk From Azinphos-methyl to Aquatic Species in Leon Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC [a] = 0.000633 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

**Table B7-18. Acute Risk From Azinphos-methyl to Aquatic Species in Leon Creek (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.000634 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.05 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-19. Acute Risk From Azinphos-methyl to Aquatic Species in Aravaipa Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.000585 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

Table B7-19. Acute Risk From Azinphos-methyl to Aquatic Species in Aravaipa Creek (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC [a] = 0.00123 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.05 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-20. Acute Risk From Azinphos-methyl to Aquatic Species in the Tennessee River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.0001120 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Low |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Low |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Low |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

Table B7-20. Acute Risk From Azinphos-methyl to Aquatic Species in the Tennessee River (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.00008961 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Low |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Low |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Low |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Low |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-21. Acute Risk From Azinphos-methyl to Aquatic Species in the Flint River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.0004148 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Low |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

Table B7-21. Acute Risk From Azinphos-methyl to Aquatic Species in the Flint River (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.0004055 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Low |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Low |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | Moderate |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | Moderate |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-22. Acute Risk From Azinphos-methyl to Aquatic Species in the Sunflower River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC*** [a] ***= 0.008006 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | High |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Moderate |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | High |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Moderate |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Moderate |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

**Table B7-22. Acute Risk From Azinphos-methyl to Aquatic Species in the Sunflower River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.006026 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | High |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Moderate |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | High |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Moderate |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Moderate |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-23. Acute Risk From Azinphos-methyl to Aquatic Species in the Red River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC[a] = 0.02551 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | High |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Moderate |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Moderate |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | High |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | High |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Moderate |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Moderate |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

**Table B7-23. Acute Risk From Azinphos-methyl to Aquatic Species in the Red River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.02651 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | High |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Moderate |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | High |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | High |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | High |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Moderate |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Moderate |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

Table B7-24. Acute Risk From Azinphos-methyl to Aquatic Species in the Gila River

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.002902 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | High |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | High |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Moderate |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

**Table B7-24. Acute Risk From Azinphos-methyl to Aquatic Species in the Gila River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.001731 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 3.5 | 0.350 | Low |
| Bluegill (*Lepomis macrochirus*) | 0.0041 | 0.00041 | Moderate |
| Channel catfish (*Ictalurus punctatus*) | 3.29 | 0.329 | Low |
| Fathead minnow (*Pimephales promelas*) | 0.235 | 0.0235 | Low |
| Green sunfish (*Lepomis cyanellus*) | 0.052 | 0.0052 | Low |
| Largemouth bass (*Micropterus salmoides*) | 0.0048 | 0.00048 | Moderate |
| Yellow perch (*Perca flavescens*) | 0.0024 | 0.00024 | High |
| **Invertebrates:** | | | |
| Aquatic sowbug (*Asellus brevicaudus*) | 0.021 | 0.0021 | Low |
| Scud (*Gammarus fasciatus*) | 0.0001 | 0.00001 | High |
| Crayfish (*Procambarus* sp.) | 0.056 | 0.0056 | Low |
| Stonefly (*Pteronarcys californica*) | 0.0019 | 0.00019 | High |
| **Amphibians:** | | | |
| Fowler's toad (tadpole) (*Bufo woodhousei fowleri*) | 0.109 | 0.0109 | Low |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.2 | 0.320 | Low |

[a] EEC = Estimated environmental concentration.

Table B7-25. Acute Risk From Diflubenzuron to Aquatic Species in Ponds

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.00261 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | High |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Moderate |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00483 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | High |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Moderate |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] EEC = Estimated environmental concentration.

**Table B7-26. Acute Risk From Diflubenzuron to Aquatic Species in Neal's Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.0000834 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00232 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | High |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] EEC = Estimated environmental concentration.

**Table B7-27. Acute Risk From Diflubenzuron to Aquatic Species in the Pearl River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.00000701 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |
| ***Risk From Extreme Case Exposure: EEC[a] = 0.0000519 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] EEC = Estimated environmental concentration.

**Table B7-28. Acute Risk From Diflubenzuron to Aquatic Species in Leon Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.0000449 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |
| ***Risk From Extreme Case Exposure: EEC[a] = 0.0000449 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] EEC = Estimated environmental concentration.

**Table B7-29. Acute Risk From Diflubenzuron to Aquatic Species in Aravaipa Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.000123 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |
| ***Risk From Extreme Case Exposure: EEC[a] = 0.000470 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Moderate |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] EEC = Estimated environmental concentration.

Table B7-30. Acute Risk From Diflubenzuron to Aquatic Species in the Tennessee River

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program[a]: EEC[b] = 0.0000126 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] Diflubenzuron is not used for suppression.
[b] EEC = Estimated environmental concentration.

**Table B7-31. Acute Risk From Diflubenzuron to Aquatic Species in the Flint River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program [a]: EEC [b] = 0.0001041 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | Low |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Low |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] Diflubenzuron is not used for suppression.
[b] EEC = Estimated environmental concentration.

**Table B7-32. Acute Risk From Diflubenzuron to Aquatic Species in the Sunflower River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program [a]: EEC [b] = 0.008006 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | High |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Moderate |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] Diflubenzuron is not used for suppression.
[b] EEC = Estimated environmental concentration.

**Table B7-33. Acute Risk From Diflubenzuron to Aquatic Species in the Red River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program [a]: EEC [b] = 0.02551 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | High |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | High |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] Diflubenzuron is not used for suppression.
[b] EEC = Estimated environmental concentration.

Table B7-34. Acute Risk From Diflubenzuron to Aquatic Species in the Gila River

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program [a]: EEC [b] = 0.002902 mg/L*** | | | |
| **Fish:** | | | |
| Bluegill (*Lepomis macrochirus*) | 660 | 66.0 | Low |
| Channel catfish (*Ictalurus punctatus*) | 370 | 37.0 | Low |
| Fathead minnow (*Pimephales promelas*) | 430 | 43.0 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia* sp.) | 0.0015 | 0.00015 | High |
| Scud (*Gammarus pseudolimnaeus*) | 0.025 | 0.0025 | Moderate |
| Stonefly (*Skwala* sp.) | 57.5 | 5.75 | Low |
| **Amphibians** | No data | — | — |

[a] Diflubenzuron is not used for suppression.
[b] EEC = Estimated environmental concentration.

**Table B7-35. Acute Risk From Methyl Parathion to Aquatic Species in Ponds**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.00946 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Moderate |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | High |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-35. Acute Risk From Methyl Parathion to Aquatic Species in Ponds (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.0306 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | High |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | High |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-36. Acute Risk From Methyl Parathion to Aquatic Species in Neal's Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.000516 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Moderate |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-36. Acute Risk From Methyl Parathion to Aquatic Species in Neal's Creek (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00231 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | High |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

Table B7-37. Acute Risk From Methyl Parathion to Aquatic Species in the Pearl River

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.000531 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Moderate |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-37. Acute Risk From Methyl Parathion to Aquatic Species in the Pearl River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00139 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Moderate |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-38. Acute Risk From Methyl Parathion to Aquatic Species in Leon Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.000129 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | Moderate |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

Table B7-38. Acute Risk From Methyl Parathion to Aquatic Species in Leon Creek (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.000129 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | Moderate |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-39. Acute Risk from Methyl Parathion to Aquatic Species in Aravaipa Creek**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Typical Case Exposure: EEC[a] = 0.000332 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Moderate |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-39. Acute Risk From Methyl Parathion to Aquatic Species in Aravaipa Creek (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From Extreme Case Exposure: EEC[a] = 0.00168 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | High |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-40. Acute Risk From Methyl Parathion to Aquatic Species in the Tennessee River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.0000586 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | Moderate |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | Moderate |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-40. Acute Risk From Methyl Parathion to Aquatic Species in the Tennessee River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.00007964 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | Moderate |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-41. Acute Risk From Methyl Parathion to Aquatic Species in the Flint River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.0002497 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-41. Acute Risk From Methyl Parathion to Aquatic Species in the Flint River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC [a] = 0.0002095 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-42. Acute Risk From Methyl Parathion to Aquatic Species in the Sunflower River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC[a] = 0.0004289 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Moderate |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

Table B7-42. Acute Risk From Methyl Parathion to Aquatic Species in the Sunflower River (continued)

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.006026 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Moderate |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | High |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-43. Acute Risk From Methyl Parathion to Aquatic Species in the Red River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.003245 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | High |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-43. Acute Risk From Methyl Parathion to Aquatic Species in the Red River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC [a] = 0.003197 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | High |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

**Table B7-44. Acute Risk From Methyl Parathion to Aquatic Species in the Gila River**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From an Eradication Program: EEC [a] = 0.0002365 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 3.06 | 0.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

**Table B7-44. Acute Risk From Methyl Parathion to Aquatic Species in the Gila River (continued)**

| Representative species | $LC_{50}$ or $EC_{50}$ (mg/L) | 1/10 $LC_{50}$ or $EC_{50}$ (mg/L) | Risk level |
|---|---|---|---|
| ***Risk From a Suppression Program: EEC[a] = 0.00005797 mg/L*** | | | |
| **Fish:** | | | |
| Black bullhead (*Ictalurus melas*) | 6.64 | 0.664 | Low |
| Bluegill (*Lepomis macrochirus*) | 4.38 | 0.438 | Low |
| Channel catfish (*Ictalurus punctatus*) | 5.24 | 0.524 | Low |
| Fathead minnow (*Pimephales promelas*) | 8.9 | 0.890 | Low |
| Green sunfish (*Lepomis cyanellus*) | 6.86 | 0.686 | Low |
| Largemouth bass (*Micropterus salmoides*) | 5.22 | 0.522 | Low |
| Yellow perch (*Perca flavescens*) | 13.06 | 1.306 | Low |
| **Invertebrates:** | | | |
| Daphnia (*Daphnia magna*) | 0.00014 | 0.000014 | High |
| Daphnia (*Simocephalus serrulatus*) | 0.00037 | 0.000037 | High |
| Damselfly (*Ischnura verticalis*) | 0.033 | 0.0033 | Low |
| Crayfish (*Procambarus clarki*) | 0.003 | 0.0003 | Low |
| **Amphibians:** | | | |
| Western chorus frog (tadpole) (*Pseudacris triseriata triseriata*) | 3.7 | 0.370 | Low |
| True frog (*Rana* sp.) | 8 | 0.800 | Low |

[a] EEC = Estimated environmental concentration.

# Section B8

## Environmental Fate and Transport

### Introduction

This section presents information on the environmental behavior and fate of the chemicals considered for use in boll weevil control, including drift, potential runoff, and leaching, and on the models used to predict the fate of these chemicals in the environment. Although the chemicals considered in this analysis are unique, they generally behave similarly in terms of reactions they will undergo in the environment, such as volatilization, photodegradation (light degradation), biodegradation (microbial degradation), and hydrolysis (water degradation). Basic information, such as the water solubility and vapor pressure of the chemical, also is provided.

Mathematical models were used to predict the concentration of an insecticide in the air and water and on plant surfaces, and to predict their fate and transport. Such models provide a reasonable answer to the question of the fate of the insecticides at a greatly reduced cost. A great deal of time, effort, and money would be required to monitor all potential receptors from the National Boll Weevil Cooperative Control Program in one State, and the potential impacts of the program across the entire Cotton Belt would still be unknown. Modeling provides an inexpensive and reliable alternative for predicting the fate and transport of chemicals in the environment.

### Models Used in This Analysis

This analysis used three different models: AGricultural DISPersal (AGDISP), Groundwater Loading Effects of Agricultural Management Systems (GLEAMS), and EXposure Analysis Modeling System II (EXAMS II). AGDISP is used to model the atmospheric "drift" (uncontrolled transport of spray into nontarget areas) of the insecticides as they are released from an aircraft. Pesticides are applied as very fine droplets or mists and are subject to wind and normal atmospheric turbulence, as well as the turbulence created by the application aircraft—all of which can contribute to drift. The AGDISP user inputs aircraft characteristics, application system characteristics, pesticide characteristics, and application variables such as aircraft speed and wind speed and direction. The AGDISP model then predicts the quantity of chemical that might drift offsite under various conditions.

An important feature of the second model—GLEAMS—is its ability to predict the movement and degradation of pesticides in the plant rooting zone. Pesticides that pass through the rooting zone may then enter groundwater aquifers. This groundwater can then flow to discharge points, such as rivers, where the pesticides in the water could affect nontarget organisms. Precipitation may wash pesticides from a field as water and suspended particle runoff, or pesticides can be leached through the rooting zone by precipitation. By predicting the amount of pesticide lost from a field during a precipitation event, it is then possible to predict the pesticide concentration in a stream or river due to runoff from which a person or animal might drink.

The third model, EXAMS II, predicts the fate and transport of chemicals in aquatic environments. Many factors affect the transport and fate of pesticides in rivers, such as microbial degradation; pesticide adsorbance to river sediments, which makes the pesticide unavailable for aqueous transport; and mixing of the river water, which creates a homogeneous mass of contaminated water. Using these factors, the concentration of a chemical can be predicted for any point in a river that received the chemical from some point upstream. In this analysis, the output from GLEAMS is used to calculate the mass loadings of insecticides for input to EXAMS II, which then predicts the concentration of the chemical at some downstream point in the modeled river.

Common to all three models is an assumption of the insecticide application rate. Table B8-1 lists the insecticides considered for use and the application rates to be used for boll weevil eradication and suppression programs. (This information is described in chapter 2 of this EIS.)

**Table B8-1. Program Insecticide Treatment Application Rates**

| Insecticide | Application rate (lb a.i./acre) |
|---|---|
| Malathion | 1.17[a] |
| Azinphos-methyl | 0.25 |
| Diflubenzuron | 0.125 |
| Methyl parathion | 0.50 |
| Xylene (Inert ingredient in microencapsulated formulation of methyl parathion) | 0.05 |

[a] West Texas Containment Program uses 0.88 lb a.i./acre.

## Environmental Fate and Properties of the Insecticides

### Malathion

#### Chemical and Physical Properties

Malathion, an organophosphate insecticide, is a colorless-to-light-amber liquid at standard conditions (25°C, 1 atmospheric pressure). The preferred chemical name is O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate (Dobroski and Lambert, 1984). The physical and chemical properties of malathion are listed in table B8-2.

**Table B8-2. Physical and Chemical Properties of Malathion**

| | |
|---|---|
| Purity | 98.5% to 99.5% (analytical grade)<br>91.5% (technical grade) |
| Boiling point | 156°C @ 0.7 torr[a] |
| Melting point | 2.85°C |
| Refractive index | 1.4985 (25°C) |
| Vapor pressure | $1.25 \times 10^{-4}$ mm Hg (20 to 25°C) |
| Solubility | 145 ppm (20 to 25°C) |

[a] 760 torr = 1 atmosphere.

Source: Dobroski and Lambert, 1984.

## Fate in Soil

Numerous values for malathion's half-life in soil have been reported. In this analysis, a half-life of 3 days was used for malathion breakdown in soil (according to a conversation between Tim Mulholland of LABAT-ANDERSON Incorporated and Mr. Charles Galley of American Cyanamid, August 1990). EPA (1986a) cites a half-life of 1 day. In alkaline soils with low organic content and low microbial populations, basic hydrolysis (chemical degradation) may be the primary reaction in the degradation of malathion. Reaction half-lives ranging from 7.5 to 11 days were found in rangeland with low organic content (Buckman and Brady, 1969).

In soils with high levels of organic matter, such as decayed vegetation, degradation of malathion occurs by enzymes (protein catalysts) excreted by bacteria (exoenzymes) and by nonbiological hydrolysis (reaction with water). Microbial exoenzymes break down malathion in soil humus. Degradation by enzymes in soil humus is the most rapid process; malathion is rapidly degraded in moist soils with significant organic content (Gibson and Burns, 1977). A half-life of one-half day has been reported in soils (Curley and Donohue, 1986). Microbes that metabolize malathion include species of the bacteria *Anthrobacter* and *Rhizobium* and the fungi *Trichoderma* (Matsumura and Boush, 1966; Walker and Stojanovic, 1973).

Malaoxon, a common soil degradation product of malathion, has a toxicity level similar to that of malathion. Degradation of malaoxon is primarily by basic hydrolysis (Pascal and Neville, 1976). Half-lives of 3.9 to 5 days were found in soils of pH 7.2 to 8.2, respectively, indicating that basic hydrolysis will lead to rapid degradation of malaoxon under soil conditions found in many areas of the United States.

Transport of malathion from the soil environment to the atmosphere should be negligible because malathion has low volatility with a vapor

pressure of $1.25 \times 10^{-4}$ mm Hg at 20 to 25°C. Because of its adsorption coefficient (20 milliliters per gram (mL/g), EPA, 1986a; 892 mL/g, Curley and Donohue, 1986), malathion has a tendency to adsorb to soils from water. As the organic carbon content of the soil increases (as in the relatively higher organic carbon content of agricultural soils relative to surrounding nonagricultural soils), malathion will bind to these soils more strongly, making it less available for leaching.

## Fate in Air

Photolysis of malathion and related compounds is too slow to be considered important to its degradation (Toia et al., 1980). However, the low volatility of malathion discounts both the likelihood of its presence in air as a vapor and its persistence in the atmosphere. Volatilization is not expected to be an important transport mechanism.

## Fate in Water

Malathion is degraded in aquatic environments through basic hydrolysis and microbial activity. Wolfe et al. (1977) found a 36-hour half-life for malathion from basic hydrolysis (pH 8, 27°C). Degradation products and reaction intermediates include DPTA, diethyl fumarate, monocarboxylic and dicarboxylic acids of malathion, and thiosuccinic acid. Malathion monoacids also are products of hydrolysis and have a half-life of 26 days for inorganic degradation. Biological degradation has been reported to eliminate malathion from river water in 28 days, with 75 percent removed in 1 week (Eichelberger and Lichtenberg, 1971). Malathion monoacids have been detected as the primary degradation products from biological reactions. The monoacids persist after malathion has been eliminated (Bourquin, 1977). The degradation products of biological reactions are eliminated only by further degradation reactions (Wolfe et al., 1977). The degradation of malathion may be accelerated by photolysis under ultraviolet radiation. Natural river water with a large amount of organic matter resulted in a half-life for malathion of 15 to 16 hours under sunlight photolysis (Wolfe et al., 1977).

Malathion may be removed from aquatic environments by adsorption to suspended particulates (half-life of 3 days for estuarine sediments, according to Walker, 1976). Because of its physical properties, malathion is not removed from aquatic environments by volatilization or precipitation as a solid.

## Fate on Plants

Degradation half-lives of 15 to 21 hours (Saini and Dobough, 1970) and 5 days (Nigg et al., 1981) have been reported for malathion on plant surfaces. Half-lives of ultra low volume (ULV) applications of malathion at 29.4 and 40.5°C were 21 and 15 hours, respectively. The half-life of malathion residues on citrus foliage was approximately 5.2 days. Residues of emulsifiable concentrate (EC) have half-lives

approximately half the half-lives of ULV residues. Degradation or disappearance of malathion from plant surfaces showed varying rates. The interval for complete dissipation of malathion by bioassay was 5 days on bean plants and 6 days on clover plants. For peaches, the safe interval between malathion treatment and consumption was 1 to 2 days (Dobroski and Lambert, 1984). Trace levels of malathion on plants after 1 week have been found in other studies (Kashyap and Hameed, 1982; as cited in Dobroski and Lambert, 1984).

Malathion has been found to damage a variety of fruit trees and vegetable plants (Thomson, 1979), including string beans, apples, Bosch pears, cherries, European grapes, and cucurbits. Some ornamental plants also are affected by malathion. Phytotoxicity of malathion to forested areas was not observed after application of 0.72 lb active ingredient per acre (a.i./acre) (Giles, 1970).

### Bioaccumulation

The bioaccumulation potential for malathion is low. Its low octanol-water partition coefficient (780) and high solubility (145 mg/L at 18°C) reflect its low potential for accumulation in lipids (Dobroski and Lambert, 1984). In acidic waters, where malathion is more stable, carp did not bioaccumulate malathion significantly above the level in the water (Bender, 1969). Retention after exposure revealed a half-life of 1 hour in tissues, reflecting relatively rapid elimination of malathion from tissues after cessation of exposure (Kenaga and Goring, 1980; as cited in Dobroski and Lambert, 1984). American Cyanamid (1986) reported a bioconcentration factor (BCF) of 37.

## Azinphos-methyl

### Chemical and Physical Properties

Azinphos-methyl (S-(3,4-dihydro-4-oxobenzo(d))-(1,2,3)-triazin-3-yl methyl) is a brown, waxy solid under ambient conditions. The physical and chemical properties of azinphos-methyl are given in table B8-3 (USDA, 1985).

### Fate in Soil

The degradation rate of azinphos-methyl in soil depends on a number of factors, including soil moisture, organic content, and temperature, as well as insecticide application practices.

In a study on the effects of azinphos-methyl formulation on its soil degradation, azinphos-methyl was most persistent when applied in granular form and then tilled into the soil to a depth of 4 to 5 inches (Schulz et al., 1970; as cited in USDA, 1985). Approximately 50 percent of the compound was lost over a period of 28 days. In contrast, when azinphos-methyl was applied as an emulsifiable concentrate and left on the soil surface, approximately 50 percent was lost in a period of 12 days.

**Table B8-3. Physical and Chemical Properties of Azinphos-methyl**

| | |
|---|---|
| Melting point for technical grade | 73°C, pure; 65 to 68°C |
| Solubility | 29 mg/L at 25°C |
| Vapor pressure | $<10^{-5}$ mm Hg |
| Octanol-water partition coefficient | 360 at 20°C |

Source: USDA, 1985.

When soils were subjected to deliberate or accidental spills (Staiff et al., 1975), azinphos-methyl was rather immobile. This study was performed in a sandy loam soil that would be susceptible to some leaching, but not as strongly as a strictly sandy soil and under conditions of 25 centimeters per year (cm/yr) rainfall and normal temperature ranges for a temperate climate. The movement of spilled azinphos-methyl concentrate was followed for 8 years. After 8 years, surface azinphos-methyl concentrations were reduced to 2 to 3 percent of the original soil concentration, and azinphos-methyl was not detected below a depth of 37.5 cm. Similar studies with more dilute solutions of azinphos-methyl gave similar results, with more rapid degradation of azinphos-methyl.

Azinphos-methyl seems to be degraded in soils by biotic and abiotic actions. In wet (50-percent saturation), sterilized soil, the half-life of azinphos-methyl at 25°C was 29 days (Iwata et al., 1975; as cited in USDA, 1985). Under similar conditions, natural septic soil produced an azinphos-methyl half-life of 13 days.

Specific microbial degradation of azinphos-methyl was studied by Engelhardt et al. (1981; as cited in USDA, 1985). Several genera of bacteria were assayed, and each showed the ability to transform azinphos-methyl. In further studies, it was found that the test medium also was capable of producing the same degradation products through chemical degradation, but at a much slower rate.

### Fate in Air

Like most pesticides, azinphos-methyl has an extremely low vapor pressure, which, along with its adsorption to soil, decreases the possibility of azinphos-methyl volatilization.

The photolytic degradation of azinphos-methyl has been studied in the aquatic environment (Anderson et al., 1974; as cited in USDA, 1985), but not in the air. Anderson et al. (1974; as cited in USDA, 1985) reported that azinphos-methyl does degrade under ultraviolet and sunlight conditions in water. No experimental measurements of these processes in air have been performed.

## Fate in Water

As with all organophosphate insecticides, azinphos-methyl hydrolyzes (that is, reacts with water) in natural water. This hydrolysis depends on temperature and pH.

The hydrolysis of azinphos-methyl has been measured by Heuer et al. (1974; as cited in USDA, 1985). These experiments were performed in distilled water. In natural waters, degradation would occur more rapidly because of the presence of bacteria. Azinphos-methyl also would be removed from the water column by its adsorption to suspended organic matter. At pH 8.6 and a temperature of 25°C, the half-life of azinphos-methyl was 27.9 days; at 40°C, the half-life was reduced to 7.2 days. When the pH was increased to 9.6, the half-life was 2.4 days at 25°C, and 0.65 days at 40°C. These results point to the strong influences that increasing temperature and pH have on the degradation of azinphos-methyl.

Azinphos-methyl also was incubated under anaerobic conditions in the sediments from a natural body of water (de Heer, 1979; as cited in USDA, 1985). At a temperature of 20°C and at pH 6.8, the measured half-lives of replicate experiments were 10 and 8.9 days.

In another experiment by de Heer (1979; as cited in USDA, 1985), the degradation of azinphos-methyl was measured in simulated conditions of farm drainage ditches. Degradation half-lives ranged from 0.63 to 7.3 days. The presence of a sediment layer did not influence the degradation rate of the dissolved material, and the degradation rate in the water column was more rapid than in the sediments.

The stability of azinphos-methyl in farm ponds has been reported by Anderson et al. (1974; as cited in USDA, 1985). Anderson's evidence comes from Meyer (1965). Following the direct application of azinphos-methyl to a farm pond, the half-life was measured as 2 days at pH 7.2 to 8.0. Similarly, Anderson et al. (1974; as cited in USDA, 1985) reported the work of Flint et al. (1970), in which azinphos-methyl also was sprayed on a pond. The pH of the pond in this experiment was 6.9 and yielded a half-life of 1.2 days. A similar experiment run concurrently at pH 7.0 in a phosphate buffer at the same temperature in the laboratory yielded a half-life of 10 days. The difference between the results of the two experiments was due to the presence of bacteria in the farm pond, as well as photodegradation from sunlight.

## Fate on Plants

As reported in a review article (Anderson et al., 1974; as cited in USDA, 1985), azinphos-methyl does not affect the physiological processes of protected plants to any appreciable extent. It is absorbed into the waxes and oils of plant cuticles and other surfaces.

Azinphos-methyl seems highly susceptible to removal from plant surfaces by rainfall when compared with other insecticides. In studies conducted under conditions of high rainfall (up to 11.42 inches over a 16-day period following application), the effective half-life of azinphos-methyl was 1.3 days (Keiser, 1968; as cited in USDA, 1985). Under less severe conditions (rainfall of 0 to 0.44 inches over a 16-day period following application), the effective half-life for azinphos-methyl was 24 days.

In another study (McMechan et al., 1972; as cited in USDA, 1985), azinphos-methyl was deliberately applied to apple trees just before a rainfall. Six hours after the azinphos-methyl spray had dried, a 1.75 cm, 10-hour rainfall occurred, which removed 41 percent of the original material. In a similar experiment, a 0.3-cm, 3.5-hour rainfall occurred 5 hours after the insecticide spray had dried; this rainfall removed 12 percent of the original quantity of azinphos-methyl. For comparison, azinphos-methyl was again applied to the apple trees. During the subsequent week, there was no precipitation, and 7 percent of the material was lost from the trees.

Radiolabeled azinphos-methyl was applied to corn and beans in a study to measure the photodegradation of the insecticide on plants (Liang and Lichtenstein, 1976; as cited in USDA, 1985). The treated leaves were exposed to 8 hours of sunlight. After this period, between 52.2 and 65.3 percent of the applied material was recovered from exposed leaves, compared to a recovery range of 86.3 to 93.5 percent for leaves that were kept in the dark. In addition, the insecticidal effectiveness of the material on the exposed leaves was reduced.

### Bioaccumulation

No specific information on the bioaccumulation of azinphos-methyl is available. For this risk analysis, the estimated bioconcentration factor (BCF) is 40, based on calculations from an equation by Kenaga and Goring (1978; as cited in Lyman et al., 1982).

## Diflubenzuron

### Chemical and Physical Properties

The physical and chemical properties of diflubenzuron, N-[[(4-chlorophenyl)amino]carbonyl]-2,6-difluorobenzamide, are presented in table B8-4. Technical diflubenzuron (more than 95 percent pure) is an odorless, white to off-white crystalline solid. It is a substituted urea-type insecticide that functions by inhibiting chitin synthesis in insects, especially larvae and molting insects.

### Fate in Soil

The degradation of diflubenzuron in soil is rapid, with half-life most directly dependent on the particle size and microbial activity of the

**Table B8-4. Physical and Chemical Properties of Diflubenzuron**

| | |
|---|---|
| Melting point | 210 to 230°C |
| Solubility | 0.2 mg/L, 20 to 25°C |
| Vapor pressure | $<10^{-8}$ mm Hg |
| Octanol-water partition coefficient | 5,000; 7,760 |
| Density | 1.2089 g/cm$^3$ |

Source: USDA, 1989.

particular soil (Verloop and Ferrel, 1977; Seuferer et al., 1979; Nimmo et al., 1984; all as cited in Dobroski et al., 1985). Diflubenzuron applied at a rate of 0.13 kilograms of active ingredient per hectare (0.71 lb a.i./acre) and incorporated to a depth of 7.6 cm (2.8 inches) had a half-life of less than 48 hours. Similar studies have reported the degradation of diflubenzuron in forest litter and soil (Sundaram, 1987; Sundaram et al., 1987; both as cited in USDA, 1989), where the concentration dropped from 0.46 to 0.1 parts per million (ppm) in less than 5 days, and degradation from a concentration of 2 parts per billion (ppb) to 30 parts per trillion (ppt) 3 hours after application (Jones and Kochenderfer, 1986; as cited in USDA, 1989).

In an experiment to determine the half-life of diflubenzuron as a function of applied particle size, Marx (1977; as cited in USDA, 1989) presented results that indicate a direct correlation between particle size and degradation. Particles 10 microns in diameter had a half-life of 16 weeks, while particles with a diameter of 2 microns had a reported half-life of less than 1 week.

The mobility of diflubenzuron was studied by Bull and Shaver (1980), who concluded that diflubenzuron was essentially immobile in the soils studied.

### Fate in Air

Because diflubenzuron has such a low vapor pressure (less than $10^{-8}$ mm Hg), it is not expected to volatilize to any great extent. The effects of sunlight on diflubenzuron on glass plates have been studied (Schaefer and Dupras, 1979), but no work on the atmospheric fate and impacts of photodegradation on the compound in the atmosphere was located.

### Fate in Water

A review of the fate of diflubenzuron in water concluded that diflubenzuron is rapidly degraded in neutral and alkaline waters (Dobroski and Lambert, 1985; as cited in USDA, 1989). Persistence or accumulation of diflubenzuron would occur only in acidic waters,

where the biological activity is low and biodegradation is therefore low. In most regions of the country where diflubenzuron might be used for boll weevil control, the natural waters are in the neutral to alkaline range (pH 6 to 9); therefore, degradation should be quite rapid.

When diflubenzuron degradation was studied in shallow ponds, Kingsbury et al. (1987; as cited in USDA, 1989) reported that its aqueous half-life was on the order of 0.4 to 1.4 days. It was 3 to 4 days before diflubenzuron concentrations were nondetectable in the pond sediments.

When diflubenzuron is applied to aquatic systems exposed to intense sunlight, it should degrade rapidly when the combined effects of photolysis, hydrolysis, and biodegradation are taken into account. Schaefer and Dupras (1979) reported that the photolytic half-life of diflubenzuron is approximately 81 hours (3.4 days).

Based on laboratory study results, diflubenzuron in estuarine waters may adversely affect arthropods, specifically crabs. Negative impacts may occur in estuaries if diflubenzuron concentrations are not reduced in inflowing waters by natural processes. The persistence of diflubenzuron in estuarine waters was studied by Christiansen and Costlow (1980; as cited in USDA, 1989). In their laboratory experiments, estuary water was filtered before its use and had a pH of 6.5 and a salinity of 20 ppt. The bioassay organisms in this study were crab larvae (*Rhithropanopeus harrisii*). No larvae survived to the first crab stage until after the diflubenzuron levels in the test microcosms had aged 42 days. An additional 14 to 17 days were required before there were no apparent effects on the larvae. Diflubenzuron concentrations were not measured in this experiment. The aging of the water allowed bacteria and other degradative processes to reduce diflubenzuron to concentrations that were tolerable for crab larvae.

In distilled water with an approximate pH of 6, Ivie et al. (1980) reported that diflubenzuron has a half-life of approximately 7 days. In natural waters, which have higher pH values, microbial activity, and sunlight, diflubenzuron should degrade much more quickly.

## Fate on Plants

Studies on the fate of diflubenzuron have been performed on a variety of plants, but this analysis will focus mainly on the work performed on cotton plants. Part of the effectiveness of diflubenzuron results from its persistence on plant material. Spray residues do not enter the plant and are not easily removed by precipitation (Peter, 1987; as cited in USDA, 1989).

Diflubenzuron fate studies have been performed and reported by Bull (1980), Mansager et al. (1979; as cited in USDA, 1989), and Bull and Ivie (1978). The results of each of these studies indicate that, whatever the method of application used, very little diflubenzuron enters the cotton

plant. When samples were taken of cotton leaves, 98 percent of the recovered diflubenzuron was unchanged. These results indicate that diflubenzuron on cotton leaf surfaces is not readily transformed.

When radiolabeled diflubenzuron was applied to field cotton, nearly 90 percent was unabsorbed after 14 days (Bull and Ivie, 1978). From the plant, 4.8 percent of the diflubenzuron was extracted from internal extracts, and more than 85 percent was recovered from the surface of the leaves. After a heavy rain and an additional week, 23 percent of the applied diflubenzuron could be removed from the surface of the leaf. In a parallel study in a greenhouse (no rain and exposure to sun), half of the diflubenzuron was on the cotton leaves after 28 days. In another study reported in the same paper, cotton plants received multiple doses of diflubenzuron. Most of the recovered diflubenzuron was found on old leaves, while new leaves that had grown during the experiment showed little diflubenzuron.

Similar experiments were performed by Mansager et al. (1979; as cited in USDA, 1989), but generally these were on individual plants as opposed to the field studies of Bull and Ivie (1978). They reported minimal absorption, metabolism, and translocation of radiolabeled diflubenzuron, and only trace quantities of diflubenzuron were found on the plants 48 days after initiation of the experiment.

### Bioaccumulation

Studies of the effects of diflubenzuron on animals (USDA, 1989) have been performed, but the results are applicable only to livestock. A BCF of 100 is used in the exposure analysis (USDA, 1989).

## Methyl Parathion

### Chemical and Physical Properties

Pure methyl parathion (dimethyl-4-nitrophenylphosphorothionate) is a white, crystalline solid; the technical product (approximately 80 percent purity) is light to dark tan in color (Worthing and Walker, 1983). The physical and chemical properties of methyl parathion are provided in table B8-5. Because methyl parathion is an organophosphate ester, it is extremely reactive in acidic and alkaline solutions.

**Table B8-5. Physical and Chemical Properties of Methyl Parathion**

| | |
|---|---|
| Melting point | 35 to 36°C |
| Density | 1.358 g/cm$^3$ |
| Solubility | 55 to 60 ppm (25°C) |
| Vapor pressure | $9.7 \times 10^{-6}$ mm Hg (20°C) |
| Octanol-water partition coefficient | 724 |

Sources: Worthing and Walker, 1983; Hansch and Leo, 1981.

## Fate in Soil

Methyl parathion is subject to many environmental processes in the soil: It is hydrolyzed by soil moisture, adsorbed to the organic fraction of soil, and biodegraded by soil microorganisms.

Biodegradation of methyl parathion in soil is a function of the concentration of the compound in the soil. At relatively lower concentrations, methyl parathion is degraded, while at higher concentrations the toxic effects of the insecticide may substantially reduce bacterial populations or flood the soil's inorganic reaction surfaces and therefore reduce its degradation. At methyl parathion soil concentrations of approximately 10,000 ppm, EPA (1980; as cited in EPA, 1984) reported that 0.1 percent of the insecticide that was originally present was degraded after 52 days. In an experiment at lower methyl parathion soil levels, EPA (1980; as cited in EPA, 1984) found that at a concentration of 24.5 ppm, more than 50 percent of the compound was degraded in 10 days. At methyl parathion soil concentrations of less than 100 ppm, EPA (1977; as cited in EPA, 1984) concluded that the insecticide degrades rapidly. However, this same report also found that in highly concentrated mixtures, degradation is minimal. In a simulated soil spill where the soil concentration of methyl parathion was approximately 50,000 ppm, Butler et al. (1981; as cited in EPA, 1984) recorded a 57-percent reduction in methyl parathion soil concentrations after 1 year.

Like many organophosphate insecticides, methyl parathion has been found to be readily biodegradable (EPA, 1977; as cited in EPA, 1984). Soil microorganisms rapidly degrade methyl parathion with a three-orders-of-magnitude reduction in soil concentration in approximately 3 weeks (EPA, 1977; as cited in EPA 1984). Similar levels of biodegradation (97 to 99.5 percent) also were found in another study (Spencer et al., 1979; as cited in EPA, 1984), but over a slightly longer period of time (33 days). Lastly, anaerobic degradation may be more significant for the biodegradation of methyl parathion in soils than aerobic

degradation. Adhya et al. (1981; as cited in EPA, 1984) found that biodegradation is more rapid under anaerobic conditions than aerobic conditions.

Methyl parathion is only moderately adsorbed to soil (EPA, 1984). Adsorption does not seem to be well correlated with the fraction of organic material in the soil, perhaps because of the adsorption of methyl parathion to the inorganic fraction of soils, particularly when soil moisture is low.

Because of the moderate adsorbability of methyl parathion, it is not expected to be highly mobile. Methyl parathion has an octanol-water partition coefficient that is similar to that of malathion and it should, therefore, be similarly bound to soil. In all likelihood, when the rapid soil degradation of methyl parathion is combined with its moderate leaching potential, there is little possibility that methyl parathion will be transported from soils to groundwater when applied in normal agricultural practices.

Methyl parathion has a very low vapor pressure ($9.7 \times 10^{-b}$mm Hg), which will prevent significant volatilization of methyl parathion from soil. Therefore, volatilization from soil should not be considered as a transport pathway. Most of the methyl parathion that may be detected in the air will be from its dispersal during aerial application of the insecticide and not from soil volatilization.

### Fate in Air

Information on the fate of methyl parathion in the air is sparse. However, photolysis of the liquid compound on glass plates indicates that photolysis of methyl parathion in the air may be significant (Baker and Applegate, 1974; as cited in EPA, 1984), but this has not been measured.

### Fate in Water

In addition to photolysis, the same processes that affect the degradation of methyl parathion in the soil environment also affect its degradation in the aquatic environment. The hydrolysis of methyl parathion has been the subject of several studies. Higher temperatures and higher pH promote the hydrolysis of methyl parathion. At a temperature of 25°C and at pH values of less than 8, it has been estimated that the freshwater half-life of methyl parathion is 72 to 89 days (Mabey and Mill, 1978; EPA, 1978; both as cited in EPA, 1984). At pH 6 to 8 and a higher temperature of 40°C, the hydrolytic half-life of methyl parathion is 8 days (EPA, 1978; as cited in EPA, 1984).

EPA (1978; as cited in EPA, 1984) also considered the direct photolysis of methyl parathion and estimated that it may be significant, especially in the summer months. During the summer, with water pH 5 to 6 and water temperature at 28°C, the aquatic photolytic half-life was 8 days; the winter photolytic half-life under similar conditions was 38 days.

As with soil, adsorption of methyl parathion to suspended organic matter should significantly reduce the available concentration of the insecticide in the water column.

### Fate on Plants

The fate of methyl parathion on plants has not been thoroughly studied. One study (EPA, 1979; as cited in NLM, 1988) did report that the insecticide was almost entirely metabolized by corn 4 days after applying methyl parathion as a foliar spray.

### Bioaccumulation

Methyl parathion does not bioaccumulate. Within organisms, its rapid metabolism prevents it from being absorbed into tissues (Kenaga, 1980; as cited in NLM, 1988). A BCF of 87 is used in the exposure analysis (Environmental Fate Database, 1990).

## Xylene

### Chemical and Physical Properties

Xylene, a common solvent used throughout industry, is a general name that refers to the ortho-, meta-, and para-isomers of dimethyl benzene. Under ambient conditions, xylene is a clear liquid with a sweet, but slightly pungent odor. The physical and chemical properties of xylene are presented in table B8-6. Xylene is discussed in this environmental impact statement (EIS) because it is a minor, inert component of the encapsulated formulation of methyl parathion.

### Fate in Soil and Water

The fate of xylene in soil is related to its fate in water. Much of the current research on xylene degradation focuses on the fate of xylene in the soil environment and its subsequent transfer to aquifers. Emphasis is placed on this research because xylene is found in gasoline, and spills may contaminate soil, groundwater, and surface water.

Barker et al. (1987) performed laboratory and field experiments to determine the biodegradation of the major components of gasoline (benzene, toluene, and xylene). In the laboratory portion of the study, the half-life of xylene in aquifers was approximately 35 days, with degradation highly dependent on the oxygen content of the water. Degradation rates increased under aerobic conditions. In field experiments, the gasoline components were introduced into an aquifer; after 434 days, none of the components was detected in the groundwater.

**Table B8-6. Physical and Chemical Properties of Xylene**

| | |
|---|---|
| **Melting point:** | |
| meta- | -47.9°C |
| ortho- | -25.2°C |
| para- | 13.3°C |
| **Density:** | |
| meta- | 0.8642 mg/cm$^3$ |
| ortho- | 0.8802 mg/cm$^3$ |
| para- | 0.8611 mg/cm$^3$ |
| **Boiling point:** | |
| meta- | 139.1°C |
| ortho- | 144.4°C |
| para- | 138.3°C |
| **Vapor pressure:** | |
| meta- | 10 mm Hg @ 28.3°C |
| ortho- | 10 mm Hg |
| para- | 10 mm Hg @ 27.3°C |
| **Solubility, water:** | |
| meta- | 130 mg/L |
| ortho- | 175 mg/L |
| para- | 198 mg/L |
| **Octanol-water partition coefficient:** | |
| meta- | 1820 |
| ortho- | 891 |
| para- | 1412 |

Sources: Chemical Rubber Company, 1982; EPA, 1986b; Sax, 1984.

Because xylenes are hydrophobic, nonpolar compounds, they tend to adsorb strongly to the organic fraction of soils. As the organic content of soils increases, the quantity of xylene adsorbed to the soil also will increase. Adsorption of xylene also will increase as the soil moisture content is reduced, especially during periods of drought.

Xylene volatilizes easily because of its relatively high vapor pressure. This, along with its low water solubility, tends to move xylene from the water phase into the vapor phase. Therefore, if xylene is applied to the soil surface, its greatest tendencies will be to adsorb to the soil or to volatilize. Leaching of xylene will be minor but could become significant during periods of heavy rainfall.

### Fate in Air

Xylene contains an aromatic benzene ring that strongly absorbs light, making it susceptible to photolytic degradation, particularly under the ultraviolet radiation of the sun. The extent of photolysis is uncertain, but it may play a role in xylene degradation in the air, as well as on plants and in soil and water.

## Fate on Plants

Xylene is not very water soluble and is readily absorbed onto compounds that also are not soluble in water, such as the fats, waxes, and oils of plants. The xylene absorption by plants is expected to be high for these reasons. Once absorbed into the waxy layer of the cuticle of a leaf, xylene will become immobile and subject to photolysis and other degradative processes.

## Bioaccumulation

No information was found on the bioaccumulation of xylene. The bioconcentration factor (BCF) for xylene (12) was determined by calculating the $K_{OC}$ (Kenaga and Goring, 1978; as cited in Lyman et al., 1982), which is dependent on the solubility of xylene (198 milligrams per liter (mg/L) (Verscheuren, 1983)).

# The AGDISP Model

## Estimation of Insecticide Spray Drift

This risk assessment used the computer model AGricultural DISPersal (AGDISP) to predict the spray drift of insecticides after they are released from application aircraft. (Spray drift is the lateral movement of an applied liquid either into or away from the target area.) The amount of insecticide that drifts downwind of a sprayed area depends on several important factors, including the following:

- Meteorology
- Release height
- Spray formulation
- Aircraft and spray system characteristics
- Canopy characteristics
- Topography

The pattern of insecticide deposition downwind of a spray aircraft can be quite complex, especially in areas close to the flight line, where deposits are heaviest. The initial distribution of the spray cloud in the first few seconds after release is controlled by the interaction of the spray with the aircraft wake. Helicopters produce not only a vertical downwash of air, but also strong vortices originating from the rotor tips. The nature of the wake depends on the characteristics of the helicopter, especially its weight and rotor diameter, as well as its height and flight speed. At slow speeds, the vertical downwash is quite strong, but at typical spraying speeds (greater than 50 mph), the wake forms a pair of tubular vortices that resemble the vortices produced by

fixed-wing aircraft. The aircraft wake also interacts with the crop foliage.

Transport of the spray depends on the interaction of the wake with characteristics of the spray, which are determined by the chemical formulation and the spray equipment type and usage. The droplet sizes produced by the system are a principal consideration in controlling drift and in providing proper coverage to ensure efficacy. The distribution of droplet sizes can be only partially controlled with current technology—a range of droplet sizes is always produced. The largest droplets fall out relatively quickly, while smaller droplets are dispersed more by turbulence and are carried farther. If droplets are too large, target coverage may be insufficient. Also, some dispersion of the spray is desirable to spread the swath more evenly and to penetrate target foliage adequately.

Spreading of the swath is predominantly downwind, which allows swaths to overlap for a more uniform coverage. However, if the spray is carried too far downwind, it is hard to control and may pose a hazard. The portion of the spray that is carried farthest is composed of the smallest droplets or insecticide in vapor phase that has evaporated either from airborne droplets or later from deposited droplets. The small droplets can be produced directly by spray equipment, or they can be a result of subsequent breakup or evaporation of larger droplets. Consequently, formulations and spray equipment have been designed to minimize the production of very small droplets. Restricting operations during unfavorable weather conditions also prevents the production of very small droplets.

The distance that spray is transported also depends on meteorological conditions and the density of intercepting vegetation. Drift is controlled by applying insecticides only when wind speeds are less than 10 mph. To maintain control of the spray, spraying is avoided under conditions favoring evaporation, such as unusually high temperature and low humidity.

It was assumed that fixed-wing aircraft would be used most of the time to apply program pesticides. Because AGDISP requires specific aircraft to produce the best results, a Cessna 188 AgTruck was used in the model. Aircraft characteristics were taken from the Aerial Application Equipment document (USDA, 1987). Characteristics of interest are aircraft weight, wing span, powerplant, and operating speed. The aircraft used in the program fly at a speed of approximately 120 mph.

AGDISP also requires pesticide application characteristics. An important characteristic is the type and number of nozzles that are used. Aircraft in the program applying malathion or azinphos-methyl generally use 13 8002 flat-fan nozzles. These two pesticides, when applied at their ultra low volume (ULV) formulations, require only 16 fluid ounces of concentrate per acre to achieve the desired application rate. The concentrate is not diluted with water or oil before application.

To apply a larger amount of liquid per acre (assuming constant aircraft speed and altitude) the aircraft will need to be equipped with either larger nozzles, additional nozzles, or both. Aircraft applying diflubenzuron or methyl parathion will need to use one of the above methods to achieve a higher application rate. The formulations of diflubenzuron used in the program are wettable powders and must be mixed with oil or water before application. To achieve the desired a.i./acre application rate, a total of 0.5 gallons of finished spray per acre must be released by the aircraft. The formulation of methyl parathion used in the program comes as a liquid concentrate but must be mixed with water before application. A total of 2 gallons of finished spray must be applied per acre.

In order to apply the amount of finished spray required for either diflubenzuron or methyl parathion application, the 8002 flat-fan nozzle would not be feasible because too many 8002 flat-fan nozzles would be required. A larger nozzle with a higher delivery rate would be needed. However, to be conservative (that is, provide for the greatest margin for safety) in this analysis, it was assumed that all pesticides will be applied with the same nozzle configuration as is used for malathion or azinphos-methyl. This is because a larger nozzle delivers larger droplets, which produce less drift.

Another characteristic of the application required in the model is the droplet frequency distribution (the frequency with which droplets of various diameters are produced by a particular nozzle). The drop spectra is typically obtained from wind tunnel tests performed with a specified material and nozzle under certain operating conditions. These operating conditions include aircraft speed, nozzle orientation, and delivery pressure. There are no results in the literature from wind tunnel tests performed using the exact conditions present in the boll weevil program. In fact, there are very little data available on drop spectra released from the 8002 flat-fan nozzle. Therefore, data describing the droplet frequency distribution from the smaller 8001 flat-fan nozzle were used in the model to determine spray distribution (Continuum Dynamics, 1990). Because smaller nozzles produce smaller droplets, which are more likely to drift, the selection of the 8001 flat-fan nozzle for modeling purposes was conservative.

The droplet size frequency from the 8001 flat-fan nozzle used in the AGDISP model is presented in table B8-7. The wind tunnel test that was performed to obtain these results used an 8001 flat-fan nozzle releasing directly downward; aircraft speed was simulated to be 120 mph. Both of these parameters match the operating procedures used in the boll weevil program. The wind tunnel test was run using a release material of pure water. The use of water is conservative, however, because water will evaporate more rapidly and the droplets will become smaller and drift farther.

**Table B8-7. Droplet Size Frequency Used in the AGDISP Modeling (8001 flat-fan nozzle)**

| Drop size | Drop diameter (μm) | Mass fraction |
|---|---|---|
| 1 | 56 | 0.0309 |
| 2 | 89 | 0.0861 |
| 3 | 122 | 0.1255 |
| 4 | 154 | 0.2025 |
| 5 | 187 | 0.2253 |
| 6 | 219 | 0.1653 |
| 7 | 252 | 0.0931 |
| 8 | 284 | 0.0520 |
| 9 | 318 | 0.0140 |
| 10 | 351 | 0.0036 |
| 11 | 382 | 0.0010 |
| 12 | 414 | 0.0002 |
| 13 | 447 | 0.0001 |
| 14 | 479 | 0.0003 |

The model was run assuming the aircraft flies 10 feet above the ground surface. Two separate runs of the model were completed to account for calm conditions (minimal crosswind) and extreme conditions (maximum crosswind under which the program would operate). The calm condition assumed a crosswind of 1 mph. The extreme conditions assumed that a windspeed of 10 mph was measured by field personnel at the height of 6 feet above the ground surface onsite. This is the maximum windspeed under which the pilots would apply pesticides in the program. The windspeed is slightly higher at 10 feet (the altitude of flight); the AGDISP model calculated a windspeed of 11.2 mph at an altitude of 10 feet. This value was used in modeling pesticide drift deposition.

The results of AGDISP modeling for malathion application are shown in figures B8-1 and B8-2. The output from the model is presented in terms of milligrams of malathion active ingredient drift per square meter (mg/m$^2$), with each graph showing the depositional pattern of insecticide from the aircraft and the situation being considered. The effects of a right-to-left crosswind can be noted on the graph (fig. B8-2). Table B8-8 shows the numerical interpretations of the graphs. When the depositional drift is considered in the exposure analyses (sections B3 and B6), the distances offsite refer to the distance from the edge of

Figure B8-1. Cumulative Lateral Deposition (mg/m²) of Malathion From a Cessna 188 AgTruck Applying 16 oz/acre From a Height of 10 feet With a 1-mph Crosswind

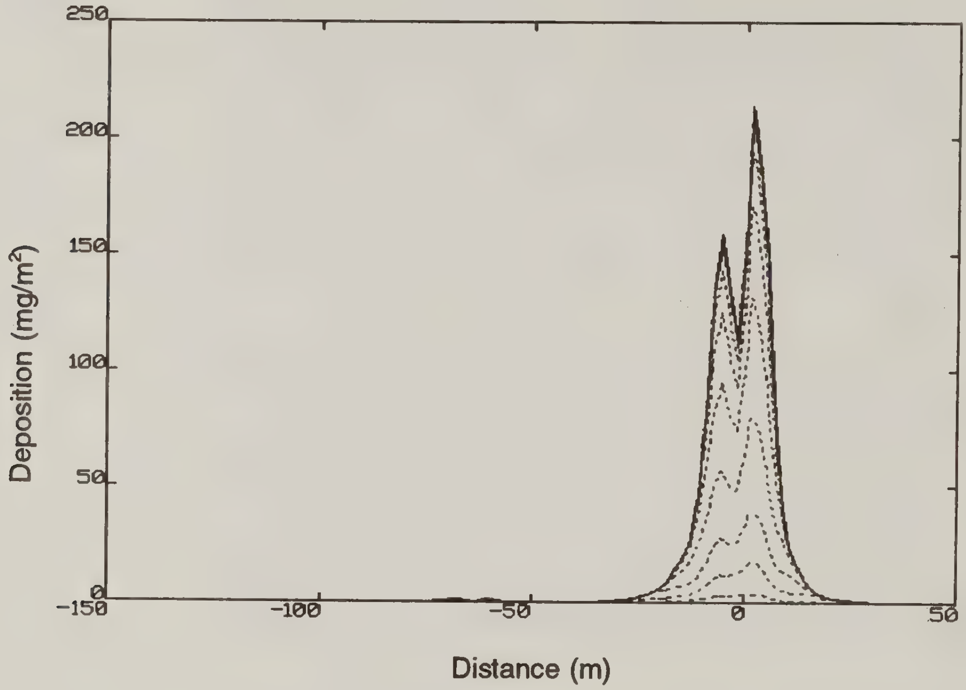



Figure B8-2. Cumulative Lateral Deposition (mg/m²) of Malathion From a Cessna 188 AgTruck Applying 16 oz/acre From a Height of 10 Feet With a 10-mph Crosswind

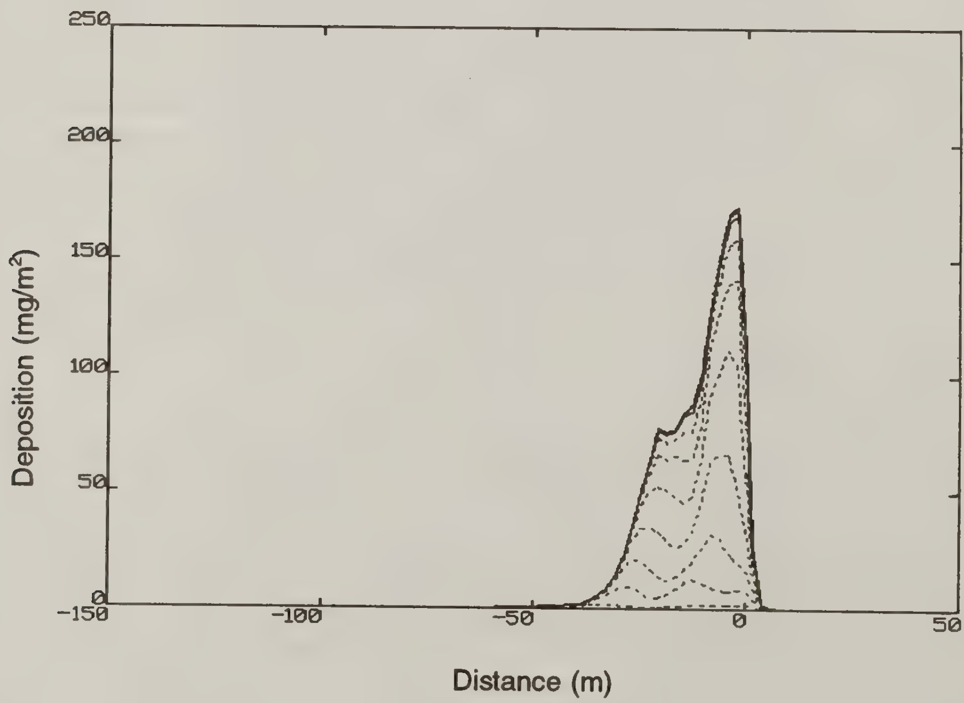


Table B8-8. Estimated Malathion Deposition From Cessna 188 AgTruck Aircraft as Calculated by the AGDISP Model

| Distance from edge of field (ft) | Deposition from 1st swath ($mg/m^2$)[a] | Deposition from 2nd swath ($mg/m^2$)[a] | Deposition from 3rd swath ($mg/m^2$)[a] | Cumulative deposition ($mg/m^2$)[a] |
|---|---|---|---|---|
| **Calm conditions (crosswind speed of 1 mph[c]):** | | | | |
| 25 | 6.8 | 0.1 | 0.0[b] | 6.9 |
| 50 | 1.4 | 0.1 | 0.0 | 1.5 |
| 100 | 0.1 | 0.0 | 0.0 | 0.1 |
| 200 | 0.0 | 0.0 | 0.0 | 0.0 |
| 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Extreme conditions (crosswind speed of 10 mph[c]):** | | | | |
| 25 | 73.3 | 1.2 | 0.3 | 74.8 |
| 50 | 33.2 | 0.8 | 0.0 | 34.0 |
| 100 | 1.2 | 0.3 | 0.0 | 1.5 |
| 200 | 0.0 | 0.0 | 0.0 | 0.0 |
| 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500 | 0.0 | 0.0 | 0.0 | 0.0 |

[a] Values indicate $mg/m^2$ as malathion active ingredient.
[b] Value indicates deposition rate less than 0.05 $mg/m^2$.
[c] Crosswind speed measured 6 feet above ground surface. Crosswind speed at altitude of flight was assumed to be higher.

the swath width. The consistent swath width is 75 feet. If drift at 25 feet offsite is of concern, the drift deposition is at a downwind distance of 62.5 feet (19 meters), which is calculated from the desire to know the drift deposition at 25 feet *plus* a consideration that the swath is 75 feet wide, half (37.5 feet) of which will be on either side of the swath centerline, or the zero point on the graph. Drift depositions at 25, 50, 100, 200, 300, and 500 feet were similarly determined. AGDISP calculates the potential drift from a single pesticide application swath. Pilots typically adjust for this drift or swath displacement by making the first pass 50 to 75 feet into the field. This allows the swath to move into the rows along the edge of the field, thereby reducing any offsite drift. The downwind drift from each swath will "tail" into the adjacent swath. At the edge of a field, it is necessary to consider the spray drift from the swath at the field edge, as well as the tailing drift from swaths away from the field edge. Estimated cumulative agrichemical drift deposition for all program chemicals (based on extrapolation from the malathion modeling) is presented in table B8-9.

## The GLEAMS Model

### Background

The Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) model, developed by the USDA Agricultural Research Service, was used to simulate insecticide fate for representative scenarios (Leonard et al., 1987; Leonard et al., 1988). GLEAMS is a computerized mathematical model developed for field-size areas to evaluate the movement and degradation of chemicals within the plant root zone under various crop management systems. The model has been tested and validated using a variety of data on pesticide and bromide movement (Leonard et al., 1987).

The hydrology and erosion components of GLEAMS are essentially the same as those of the Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) model (Knisel, 1980). CREAMS is a physically based model that has been validated using data from diverse climatic and physiographic regions (Foster and Ferreira, 1981; Knisel, 1980; Knisel et al., 1983; Lorber and Mulkey, 1982).

Improvements made during the development of GLEAMS included a new emphasis on prediction of chemical losses through leaching to groundwater and a more sophisticated handling of irrigation. Figure B8-3 illustrates the processes represented by GLEAMS. The structure and function of the model are discussed briefly here. For more detailed information, consult the GLEAMS and CREAMS documentation.

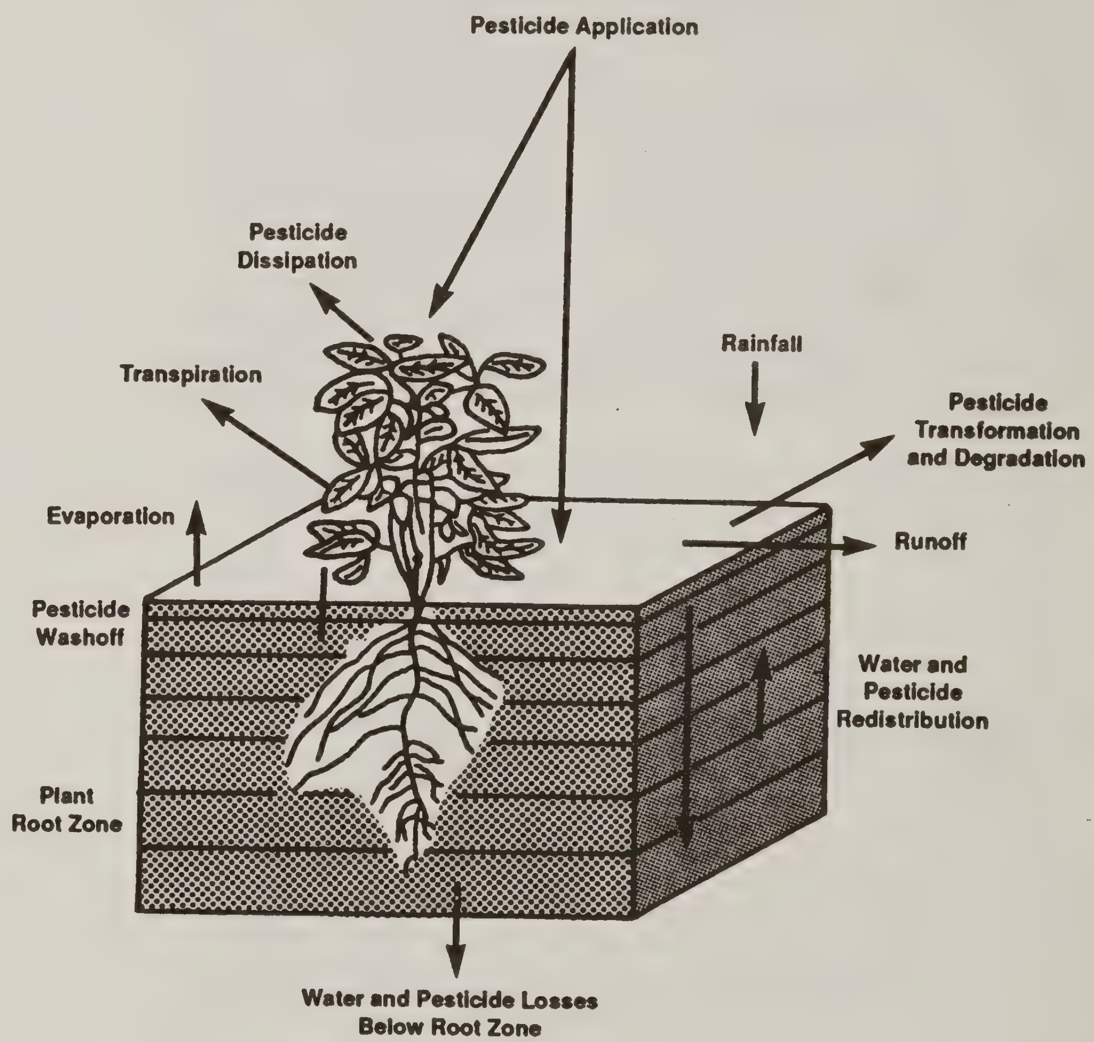
The hydrology component of GLEAMS subdivides the soil within the rooting zone into seven computational layers. The surface layer is assumed to be 1-cm thick; other layers are adjusted to account for the remainder of the rooting zone. Soils data are input by horizon (a layer of soil identified by unique characteristics) for porosity, water-retention characteristics, and organic matter. During a simulation, GLEAMS continuously computes water balance for each layer, including percolation (downward movement), evaporation, and transpiration (upward movement). Evaporation of chemicals from the soil surface is not

**Table B8-9. Estimated Cumulative Agrichemical Drift Deposition Based on Results of Malathion Drift Modeling With AGDISP**

| Distance from edge of field (ft) | Cumulative malathion deposition (mg/m²)[a] | Cumulative azinphos-methyl deposition (mg/m²)[a] | Cumulative diflubenzuron deposition (mg/m²)[a] | Cumulative methyl parathion deposition (mg/m²)[a] |
|---|---|---|---|---|
| **Calm conditions (crosswind speed of 1 mph[c]):** | | | | |
| 25 | 6.9 | 1.5 | 0.7 | 2.9 |
| 50 | 1.5 | 0.3 | 0.2 | 0.6 |
| 100 | 0.1 | 0.0 | 0.0 | 0.0 |
| 200 | 0.0 | 0.0 | 0.0 | 0.0 |
| 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Extreme conditions (crosswind speed of 10 mph[c]):** | | | | |
| 25 | 74.8 | 16.0 | 8.0 | 32.0 |
| 50 | 34.0 | 7.3 | 3.6 | 14.5 |
| 100 | 1.5 | 0.3 | 0.2 | 0.6 |
| 200 | 0.0 | 0.0 | 0.0 | 0.0 |
| 300 | 0.0 | 0.0 | 0.0 | 0.0 |
| 500 | 0.0 | 0.0 | 0.0 | 0.0 |

[a] Values indicate $mg/m^2$ as pesticide active ingredient.
[b] Value indicates deposition rate less than 0.05 $mg/m^2$.
[c] Crosswind speed measured at 6 feet above ground surface. Crosswind speed at altitude of flight was assumed to be higher.

**Figure B8-3. The Physical System and Processes Represented in the GLEAMS Model**




Source: Leonard et al. (1987)

represented, but evaporation of water can cause chemicals to move upward through the soil.

The erosion component of GLEAMS accounts not only for the basic soil particle size categories (sand, silt, and clay), but also for small and large aggregates of soil particles. Furthermore, the program accounts for the unequal distribution of organic matter between soil layers to calculate a ratio that describes the potentially greater concentration of chemicals in eroding soil than in surface soil.

The pesticide component of GLEAMS can represent chemical deposit directly on the soil, the deposit of chemicals on plant leaves, and

subsequent washoff from leaves. Degradation rates can differ between plant surfaces and soil. Degradation calculations are performed daily, as is the redistribution of chemicals from hydrologic processes. The distribution of a chemical between dissolved (water) and adsorbed (soil) states is described as a simple linear relationship and is directly proportional to the organic carbon partition coefficient, $K_{oc}$ (a property of the chemical), and the organic matter content of the soil. The calculation of extraction of chemicals from the soil surface into runoff considers adsorption to soil (assumed to be relatively rapid) and a related parameter that describes the depth of interaction of runoff water with the surface soil. Percolation of chemicals is calculated through each of the seven computational soil layers, and the amount that passes through the last soil layer is accumulated as the potential loading to groundwater.

Input data required by the GLEAMS model consist of four separate files: rainfall data, hydrology parameters, erosion parameters, and chemical parameters. Rainfall data were obtained for six representative sites: Maricopa, Arizona; Corpus Christi, Texas; Vernon, Texas; Stoneville, Mississippi; Huntsville, Alabama; and Tifton, Georgia. The data for Maricopa, Vernon, Stoneville, and Huntsville were obtained from the National Climatic Data Center in Asheville, North Carolina, in the form of standard daily precipitation files on diskettes. Daily maximum and minimum temperature files were obtained from the same source. These climatic data files cover the period from January 1, 1985, through September 1, 1988. A computer program was written to extract data from these files and to calculate monthly temperature extremes and daily rainfall in the format required by GLEAMS.

For Corpus Christi, Texas, the climatic data were simulated using a "climatic generator" program obtained from Dr. Frank Davis, USDA Agricultural Research Service, Tifton, Georgia. The program contains a data base with statistical characteristics of rainfall patterns for selected locations around the country--including Corpus Christi. For Tifton, Georgia, data were available from a previous modeling study for the period 1972 through 1975 (Computer Sciences Corporation, 1980).

In each precipitation file, additional rainfall events corresponding to 6-hour storms for a recurrence interval of 2 years were added based on a rainfall frequency atlas (Hershfield, 1961). Most other parameters were determined using tables and guidance contained in the GLEAMS program and documentation (Knisel et al., 1987) and the documentation for CREAMS (Knisel, 1980; USDA, 1984), or were based on discussions with agricultural extension and research scientists in each area. Precipitation, hydrology, erosion, and chemical parameter files were prepared for each representative scenario.

The hydrology parameter file contains information on the shape and surface features of the field, hydraulic conductivity, soil water storage, leaf area indices, and irrigation practices. This file also contains the Soil

Conservation Service "curve number," which describes the tendency for water to run off the surface of the soil.

The erosion parameter file contains information needed to calculate erosion, sediment yield, and particle composition of the sediment on a storm-by-storm basis. The input data can represent a number of optional configurations of fields, channels, and impoundments, but the representative scenarios chosen for analysis in this study all represented a single channel draining a field. Runoff leaving the channel was considered as input to receiving waters, which are typically streams and rivers. The erosion parameter file input to GLEAMS contained parameters describing soil erodibility, soil particle size distributions, slope geometry, channel geometry, watershed area, and surface roughness.

Pesticide parameter files describing the characteristics of malathion, azinphos-methyl, diflubenzuron, and methyl parathion and their particular use patterns on cotton were prepared. Information on water solubility, foliar and soil half-lives, organic carbon partitioning coefficients, the tendency for the insecticides to wash off plant surfaces, and the expected application rates and schedules was included. Though four of the insecticides were simulated simultaneously, they were treated independently by GLEAMS.

Tables listing input parameters with their definitions, suggested sources of the parameter estimates, and notes on the expected quality of the data sources are given in the CREAMS WCC user's guide (USDA, 1984). The GLEAMS parameters are the same, with a few exceptions. GLEAMS requires additional parameters describing the degradation reactions, and it uses $K_{oc}$ rather than $K_d$ to describe adsorption.

For each case, output from the GLEAMS model includes a storm-by-storm accounting of insecticide concentrations by soil layer, the movement of insecticide residues in percolating water and runoff water, and residues adsorbed to eroded soil. An auxiliary program can be used to generate graphs of the total mass per unit area of each chemical over time. Separate output files describe hydrology and erosion in more detail.

## Setup for Representative Sites

Parameters describing the physical properties and degradation rates of the four insecticides were taken from the pesticide data base provided by USDA-ARS with the GLEAMS program. Input parameters are shown in table B8-10. The water solubilities and organic carbon adsorption coefficients vary over a wide range, but all of the insecticides are expected to adsorb significantly to soil particles. The coefficient of uptake was set at 1.0 for each of the insecticides, indicating that they are expected to be taken up freely (but passively) with water entering the roots of the cotton plants. The actual amount of uptake is uncertain, but this parameter has little effect on the results of the simulations, because the amount of insecticide in solution in soil water is relatively small.

**Table B8-10. GLEAMS Input Parameters**

| Chemical coefficient | Water solubility (ppm) | Half-Life Foliar (Day) | Half-Life Soil (Days) | $K_{oc}$ | Washoff fraction | Uptake |
|---|---|---|---|---|---|---|
| Azinphos-methyl | 29.0 | 8.0 | 15 | 700.00 | 0.60 | 1.0 |
| Diflubenzuron | 0.2 | 27.0 | 9 | 0.05 | 1.00 | |
| Malathion | 145.0 | 3.0 | 3 | 1800.00 | 0.90 | 1.0 |
| Methyl parathion | 60.0 | 3.0 | 5 | 14,000.00 | 0.65 | 1.0 |

The foliar and soil half-lives are important in controlling the soil insecticide concentrations that accumulate over time, as well as the persistence of the chemicals in the soil. On foliage, diflubenzuron has the longest half-life at 27 days; malathion and methyl parathion have short half-lives of 3 days; and azinphos-methyl has an intermediate half-life of 8 days. In soil, the degradation rates are significantly different: azinphos-methyl has the longest half-life at 15 days; diflubenzuron, methyl parathion, and malathion have relatively short half-lives of 9, 5, and 3 days, respectively. The soil half-life for malathion used in the draft EIS was 7 days. For the final EIS, a soil half-life for malathion of 3 days was used, based on additional data reviewed.

The amount and timing of insecticide application are the other major determinants of soil residues. The expected application rates and timing for both the eradication and suppression programs are described in chapter 2. For the purposes of modeling, the shortest intervals between applications allowed by the eradication and suppression treatment schedules have been assumed. The highest application rates have been assumed for eradication and suppression treatments: 1.17, 0.25, 0.125, and 0.5 lb a.i./acre for malathion, azinphos-methyl, diflubenzuron, and methyl parathion, respectively. Sixty percent of the applied insecticide was assumed to be deposited on cotton foliage, and 40 percent was assumed to be deposited directly on the soil.

A 2-year storm was added to the meteorological records 2 days after the final application during the most intensive period of insecticide application. During the second and third year of the eradication program, the storms were added on November 1 for soils in Mississippi, Alabama, Georgia, and Arizona and on October 12 for Texas soils. November is a relatively dry month in Texas, and the probability of a large storm is significantly higher in October. The intensive period of insecticide application is nearly over in Texas at this time. The dates of the artificial storms for modeling the environmental fate of the insecticides under the suppression program were within 14 days of the eradication storms. They were slightly different because of the difference in application schedules. Because diflubenzuron was not applied in the first year of the program and was sparsely applied in the second

year of eradication, runoff during a 2-year storm in the third year was modeled. July 24 was selected as the artificial storm date because diflubenzuron is applied only during the early season, and nearly immeasurable levels of the insecticide were predicted during fall of the second year. The timing of these storms was chosen to model hydrologic conditions during a wet season. The storms could have been added at different times of the year, but taken as a whole, these precipitation patterns must be considered to represent extreme cases.

Six representative locations were chosen for modeling, covering a range of topographic, hydrologic, and to some extent, cotton-growing practices. At four of these locations, two different soil types were analyzed for a total of 10 site/soil combinations modeled. Although other locations, soil types, and other factors may produce somewhat different results, the 10 scenarios modeled represent a range of typical conditions that, when combined with the extreme precipitation patterns, can be expected to show potential for offsite movement of insecticide by surface runoff or percolation through soil. The 10 representative site/soil combinations used were the following:

- Alabama: Decatur silt loam
- Arizona: Shontik sandy loam
- Arizona: Trix clay loam
- Georgia: Cowerts loamy sand
- Mississippi: Dubbs very fine sandy loam
- Mississippi: Sharkey and Alligator clays
- Texas, Coastal: Orelia sandy clay loam
- Texas, Coastal: Victoria clay
- Texas, Rolling Plains: Miles fine sandy loam
- Texas, Rolling Plains: Abilene clay loam

The typical soil types, site characteristics, and cotton management practices were chosen in consultation with research and extension personnel familiar with cotton management in each area. In areas where irrigation is normally used (Arizona), typical irrigation volumes were added to the precipitation input file. Some of the more important input parameters for each site are listed in table B8-11. The typical field sizes used in the simulations ranged from 30 acres in the Southeast to 150 acres in Texas. The Soil Conservation Service runoff curve numbers shown in table B8-11 are used to determine the amount of water that runs off from the land surface as the result of a given storm. The

**Table B8-11. Site Characteristic Input Parameters (GLEAMS simulation)**

| Site | Average field size (acres) | Saturated conductivity (hr) | SCS[a] runoff curve | Soil erodibility | Surface porosity | Surface organic matter (%) | Slope |
|---|---|---|---|---|---|---|---|
| **Alabama**: | | | | | | | |
| Decatur silt loam | 30 | 0.22 | 75 | 0.35 | 0.43 | 1.0 | 0.01 |
| **Arizona**: | | | | | | | |
| Shontik sandy loam | 70 | 1.0 | 72 | 0.12 | 0.435 | 0.5 | 0.004 |
| Trix clay loam | 70 | 0.1 | 84 | 0.19 | 0.45 | 1.35 | 0.004 |
| **Georgia**: | | | | | | | |
| Cowerts loamy sand | 30 | 0.22 | 80 | 0.20 | 0.47 | 1.0 | 0.028 |
| **Mississippi**: | | | | | | | |
| Dubbs very fine sandy loam | 30 | 0.30 | 83 | 0.15 | 0.40 | 1.0 | 0.002 |
| Sharkey and Alligator clay | 30 | 0.05 | 89 | 0.15 | 0.47 | 1.0 | 0.002 |
| **Texas, Coastal**: | | | | | | | |
| Orelia sandy clay loam | 150 | 0.063 | 87 | 0.28 | 0.41 | 0.5 | 0.01 |
| Victoria clay | 150 | 0.050 | 87 | 0.32 | 0.41 | 2.0 | 0.01 |
| **Texas, Rolling Hills**: | | | | | | | |
| Miles very fine sandy loam | 150 | 0.22 | 84 | 0.24 | 0.36 | 0.9 | 0.02 |
| Abilene clay loam | 150 | 0.20 | 86.5 | 0.37 | 0.40 | 2.0 | 0.02 |

[a] SCS = Soil Conservation Service.

numbers were chosen to be realistic, but they represent moderately high runoff conditions.

## GLEAMS Simulations

The GLEAMS modeling estimated the amount of insecticide lost to runoff of both sediment and water, percolation, and the amount that remains in the soil. Detailed GLEAMS output found within this section shows insecticide runoff in water, insecticide runoff in sediment, and insecticide percolation through the soil for three rainfall events in 10 representative sites across the Cotton Belt for both eradication and suppression alternatives.

First, the surface runoff from these sites (which has the greatest mass, but lowest concentration of insecticide) is discussed. Second, soil residues over the first few years of the program are presented. Third, the potential for these insecticides to leach into groundwater is analyzed.

### Soil and Water Runoff

Predicted insecticide losses in runoff water and those adsorbed (bound to the surface) to eroded sediments for the 2-year storms are shown in table B8-12 for the eradication alternative and table B8-13 for the suppression alternative. During preliminary analyses, both 10- and 100-year storms were also modeled to determine what scenario would best represent an extreme situation. Although a higher mass of insecticide runs off with higher volumes of rain during the larger storm events, 2-year storms caused the highest insecticide concentrations in almost all cases. These storm events were used to predict the concentrations of insecticide in river water. Losses of insecticide from leaching are not expected to occur; therefore, they do not appear on these tables.

Most of the predicted insecticide losses will occur in the runoff water. The impacts on aquatic species of the insecticide losses through storm water are described in section B7 of this appendix. The variability of insecticide concentrations in runoff water is not predicted to be great when compared by site. In general, the higher the proportion of clay in a particular soil, the higher the runoff. Clay particles have a high capacity for adsorption of organic pesticides because of their molecular structure, which sand particles lack. Therefore, pesticides in runoff from soils high in clay tend to be concentrated more in the solid phase than those from sandy soils.

Several parameters not evaluated in GLEAMS serve to reduce the potential of cotton field runoff reaching surface water. Runoff from agricultural fields is sometimes collected in drainage ditches, especially in areas where water is a scarce commodity and irrigation is used to water crops. Fallow vegetation around cotton fields also tends to prevent insecticide-laden runoff from reaching surface water. The vegetation retains runoff sediment and adsorbs some insecticides in solution.

**Table B8-12. Predicted Insecticide Losses for a 2-year Storm in Runoff Water and Eroded Soil Under a Beltwide ERADICATION Program (GLEAMS simulation)**

| State/soil[a] | Malathion | | Azinphos-methyl | | Diflubenzuron | | Methyl parathion | |
|---|---|---|---|---|---|---|---|---|
| | Water (mg/L) | Soil (µg/g) | Water (mg/L) | Soil (µg/g) | Water (mg/L) | Soil (µg/g) | Water (mg/L) | Soil (µg/g) |
| AL/loam | 0.18 | 3.3 | 0.05 | 0.4 | 0.02 | 1.1 | 0.04 | 5.6 |
| AZ/loam | No runoff or leaching—no insecticide losses | | | | | | | |
| AZ/clay | 0.24 | 5.3 | 0.10 | 0.9 | 0.02 | 1.4 | 0.03 | 5.8 |
| GA/sand | 0.17 | 9.2 | 0.06 | 1.2 | 0.02 | 3.9 | 0.04 | 18.3 |
| MS/loam | 0.21 | 5.7 | 0.07 | 0.7 | 0.02 | 0.8 | 0.04 | 8.6 |
| MS/clay | 0.24 | 2.3 | 0.08 | 0.3 | 0.02 | 2.0 | 0.05 | 3.5 |
| TX/c/loam | 0.16 | 2.2 | 0.05 | 0.3 | 0.02 | 3.1 | 0.07 | 7.0 |
| TX/c/clay | 0.20 | 4.9 | 0.07 | 0.7 | 0.01 | 1.1 | 0.02 | 4.5 |
| TX/p/sand | 0.20 | 6.1 | 0.06 | 0.7 | 0.02 | 2.2 | 0.04 | 10.3 |
| TX/p/clay | 0.20 | 6.8 | 0.05 | 0.7 | 0.01 | 1.6 | 0.02 | 6.5 |

[a] AL/loam = Alabama, Decatur silt loam; AZ/loam = Arizona, Shontik sandy loam; AZ/clay = Arizona, Trix clay; GA/sand = Georgia, Cowerts loamy sand; MS/loam = Mississippi, Dubbs very fine sandy loam; MS/clay = Mississippi, Sharkey and Alligator clays; TX/c/loam = Texas, Coastal, Orelia sandy clay loam; TX/c/clay = Texas, Coastal, Victoria clay; TX/p/sand = Texas, Rolling Plains, Miles very fine sandy loam; TX/p/clay = Texas, Rolling Plains, Abilene clay loam.

Note: No leaching was predicted under any 2-year storm scenario.

**Table B8-13. Predicted Insecticide Losses for a 2-year Storm in Runoff Water and Eroded Soil Under a Beltwide SUPPRESSION Program (GLEAMS simulation)**

| State/soil[a] | Malathion | | Azinphos-methyl | | Methyl parathion | |
|---|---|---|---|---|---|---|
| | Water (mg/L) | Soil (µg/g) | Water (mg/L) | Soil (µg/g) | Water (mg/L) | Soil (µg/g) |
| AL/loam | 0.18 | 3.1 | 0.50 | 0.3 | 0.04 | 5.3 |
| AZ/loam | No runoff or leaching—no insecticide losses | | | | | |
| AZ/clay | 0.23 | 5.0 | 0.07 | 0.6 | 0.03 | 5.3 |
| GA/sand | 0.18 | 9.6 | 0.06 | 1.3 | 0.04 | 16.5 |
| MS/loam | 0.18 | 4.5 | 0.05 | 0.5 | 0.04 | 7.7 |
| MS/clay | 0.19 | 1.9 | 0.05 | 0.2 | 0.04 | 3.2 |
| TX/c/loam | 0.16 | 2.2 | 0.05 | 0.3 | 0.07 | 7.1 |
| TX/c/clay | 0.20 | 4.9 | 0.07 | 0.7 | 0.02 | 4.5 |
| TX/p/sand | 0.20 | 6.2 | 0.06 | 0.7 | 0.04 | 10.4 |
| TX/p/clay | 0.20 | 6.9 | 0.06 | 0.8 | 0.02 | 6.5 |

[a] AL/loam = Alabama, Decatur silt loam; AZ/loam = Arizona, Shontik sandy loam; AZ/clay = Arizona, Trix clay; GA/sand = Georgia, Cowerts loamy sand; MS/loam = Mississippi, Dubbs very fine sandy loam; MS/clay = Mississippi, Sharkey and Alligator clays; TX/c/loam = Texas, Coastal, Orelia sandy clay loam; TX/c/clay = Texas, Coastal, Victoria clay; TX/p/sand = Texas, Rolling Plains, Miles very fine sandy loam; TX/p/clay = Texas, Rolling Plains, Abilene clay loam.

Note: No leaching was predicted under any 2-year storm scenario.

## Soil Residues

Tables B8-12 and B8-13 illustrate the output on runoff concentrations as predicted by GLEAMS. Soil residues were also calculated by GLEAMS, and the results of a few selected sites are discussed in this section. These sites were selected to illustrate potential impacts on a variety of soil types and locations. Figures B8-4 through B8-21 support the following text.

***Eradication Program.*** GLEAMS simulations were conducted on 10 soil types in five States. The results of the analysis on pesticide loads to the soils for Mississippi Dubbs very fine sandy loam, Alabama Decatur silt loam, and Texas Rolling Plains Abilene clay loam are discussed below.

***Mississippi Dubbs Very Fine Sandy Loam.*** During the first year of the program, treatments may be provided with azinphos-methyl, malathion, or methyl parathion. Diflubenzuron would not be used during the first year. Estimated pesticide loads to the soil during the first year, as determined by the GLEAMS model, are presented in figure B8-4. When azinphos-methyl is applied to this soil type during the first year, soil residue levels could begin to rise after the first application in September and peak about the first of October at a load of approximately 0.4 kg/ha. Residues would likely decline after this time and reach negligible levels in early January. Malathion soil residue levels could rise to about 0.8 kg/ha after the first application in early September and peak at 0.6 to 0.8 kg/ha after each subsequent application through the middle of October. After this time, residues should rapidly decline to negligible levels by the middle of December. Methyl parathion residues are expected to follow approximately the same pattern as azinphos-methyl. Residues should reach a maximum soil loading of approximately 0.4 kg/ha in early October and should decline to negligible levels by late November.

After the first year of the program, the application schedule is predicted to be different, with increases in the number of applications for the year. Additionally, diflubenzuron may be applied in early season. Pesticide loadings to the Mississippi Dubbs very fine sandy loam soil during the second year are presented in figure B8-5. Azinphos-methyl residues are predicted to gradually increase in the soil because of the slow degradation of this pesticide. Azinphos-methyl residues should be present at low levels through July and then increase in early August to a peak concentration of approximately 0.9 kg/ha. The soil residue levels are then predicted to decline through the fall and winter and reach negligible levels by early March.

During the second year, diflubenzuron may be applied in June and July. Low soil residues of diflubenzuron should peak in late July at approximately 0.1 kg/ha and decline to negligible levels by late August. Malathion residues should peak at levels of about 1.4 kg/ha in early July of the second year, with a similar second peak in early

Figure B8-4. Estimated Pesticide Load in Mississippi Dubbs Very Fine Sandy Loam During the FIRST YEAR of an ERADICATION Program (shown in kg/ha)

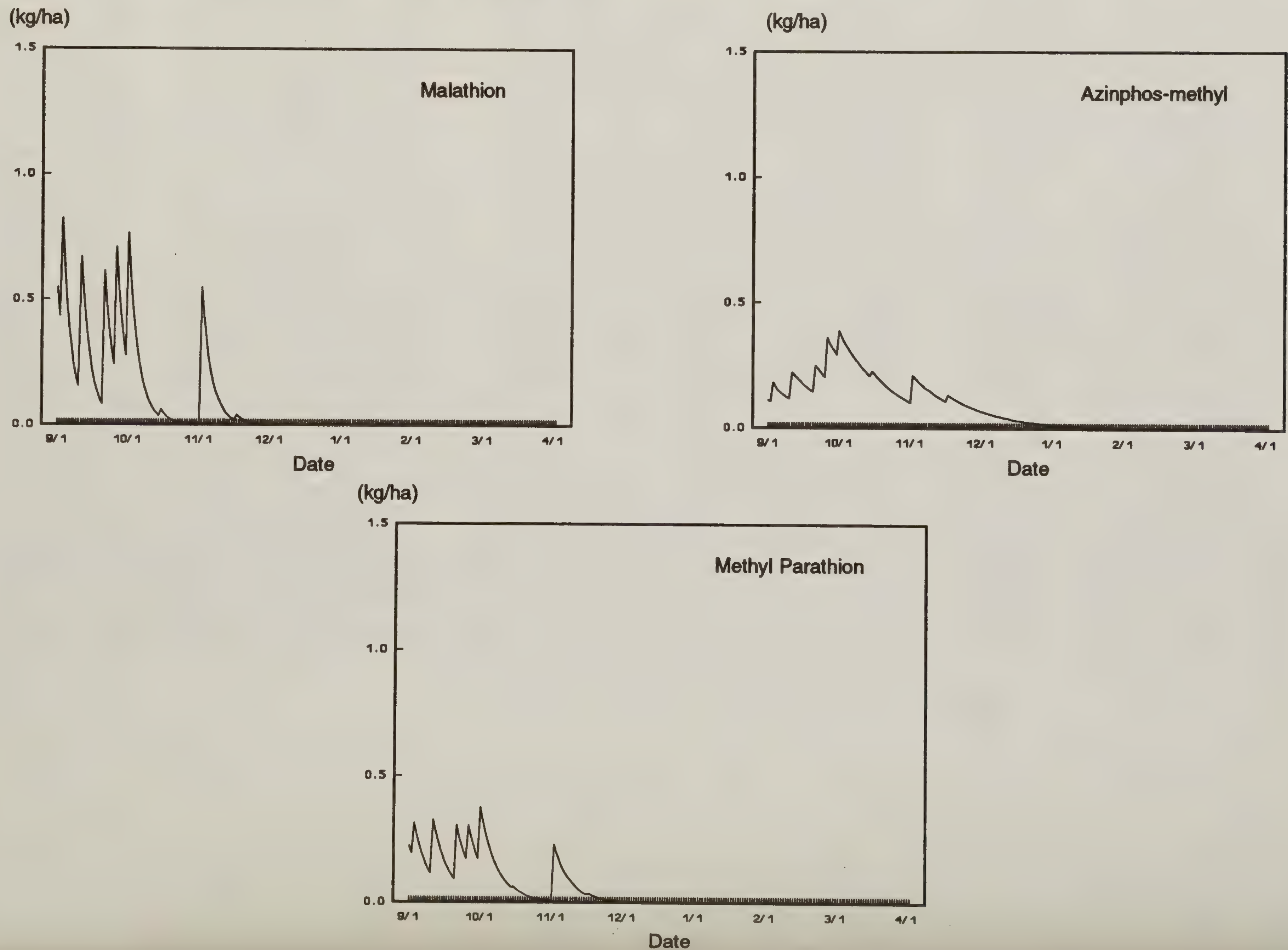


**Figure B8-5. Estimated Pesticide Load in Mississippi Dubbs Very Fine Sandy Loam During the SECOND YEAR of an ERADICATION Program (shown in kg/ha)**

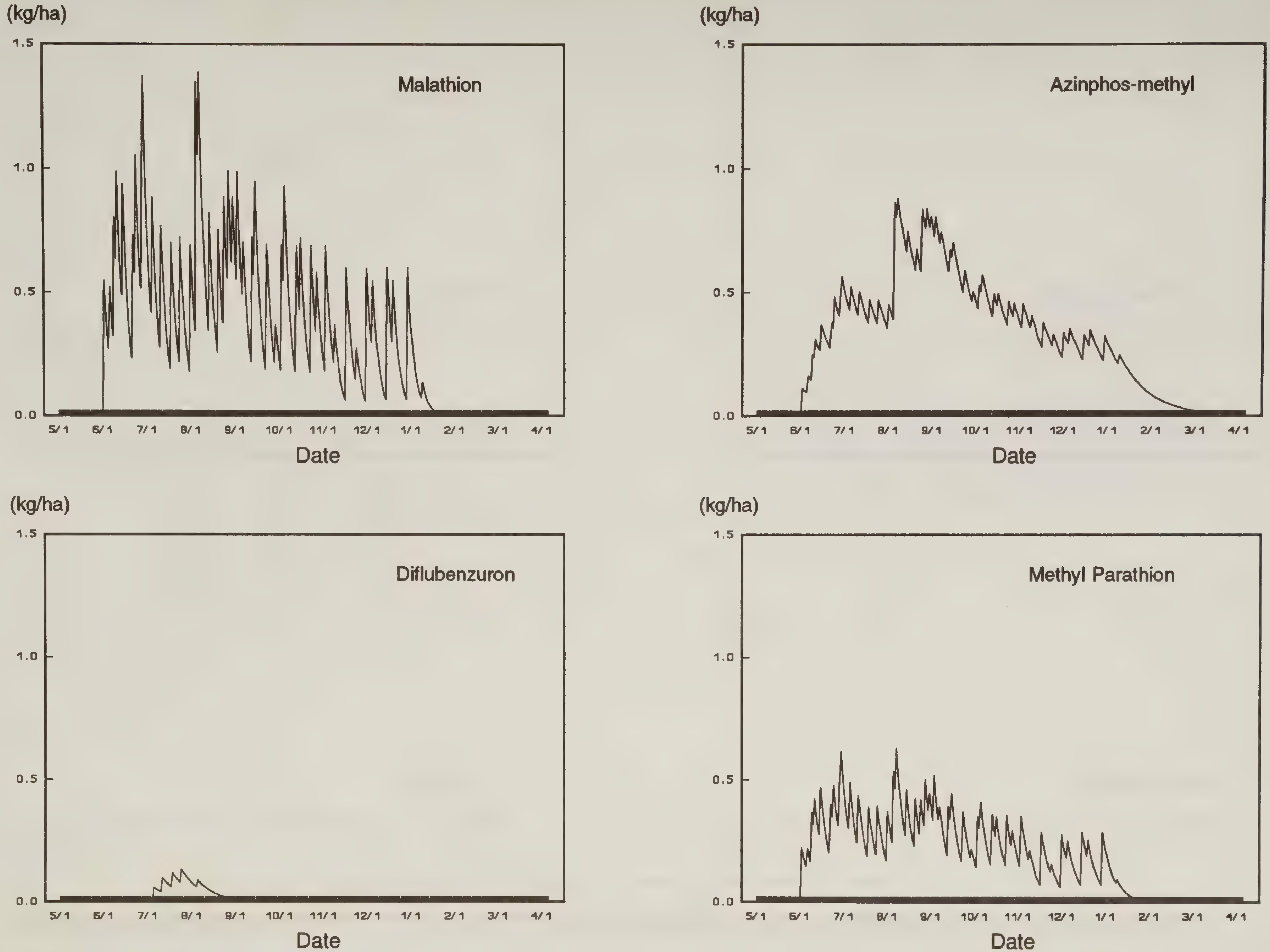


**Figure B8-6. Estimated Pesticide Load in Mississippi Dubbs Very Fine Sandy Loam During the THIRD YEAR of an ERADICATION Program (shown in kg/ha)**

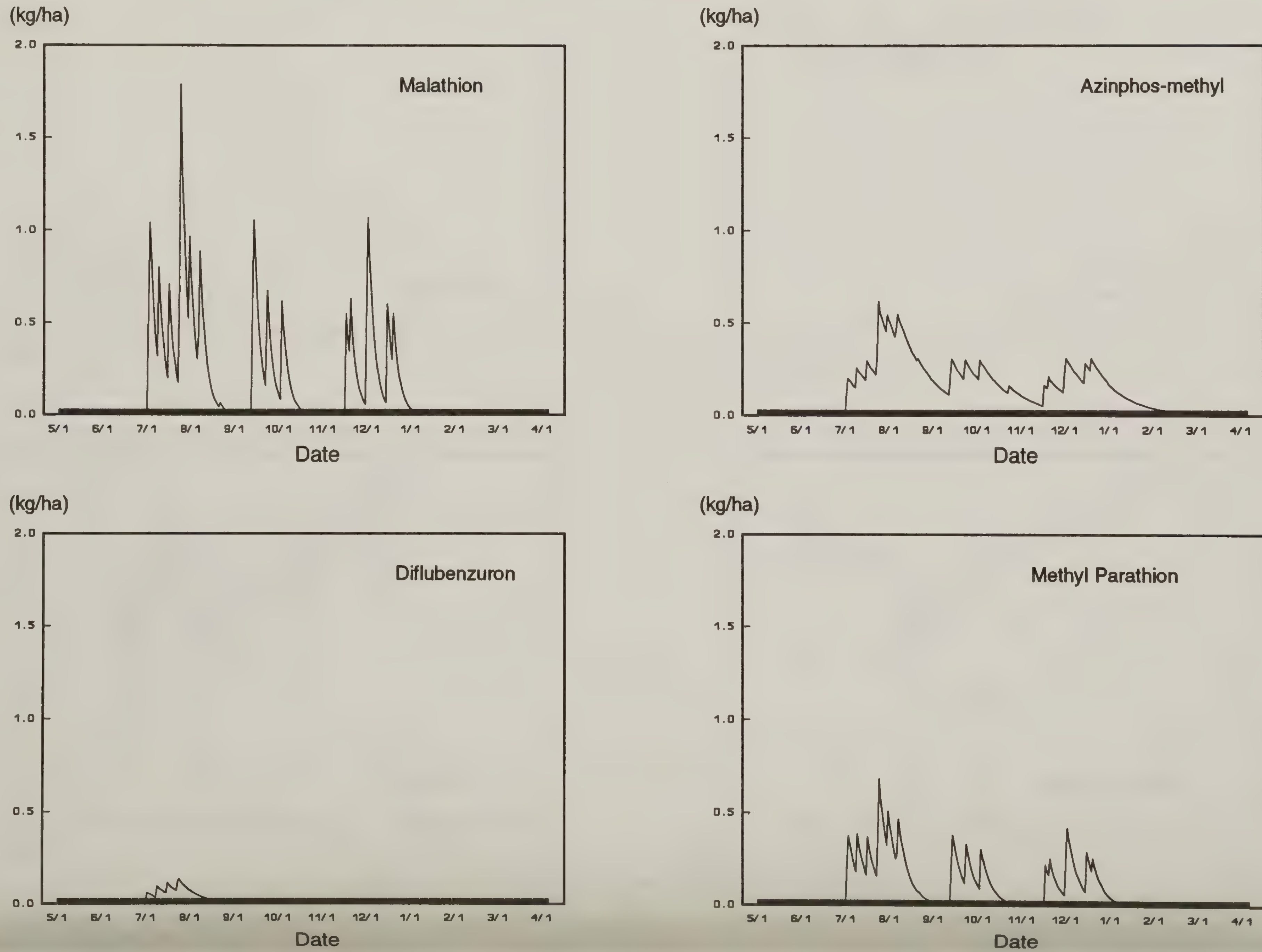
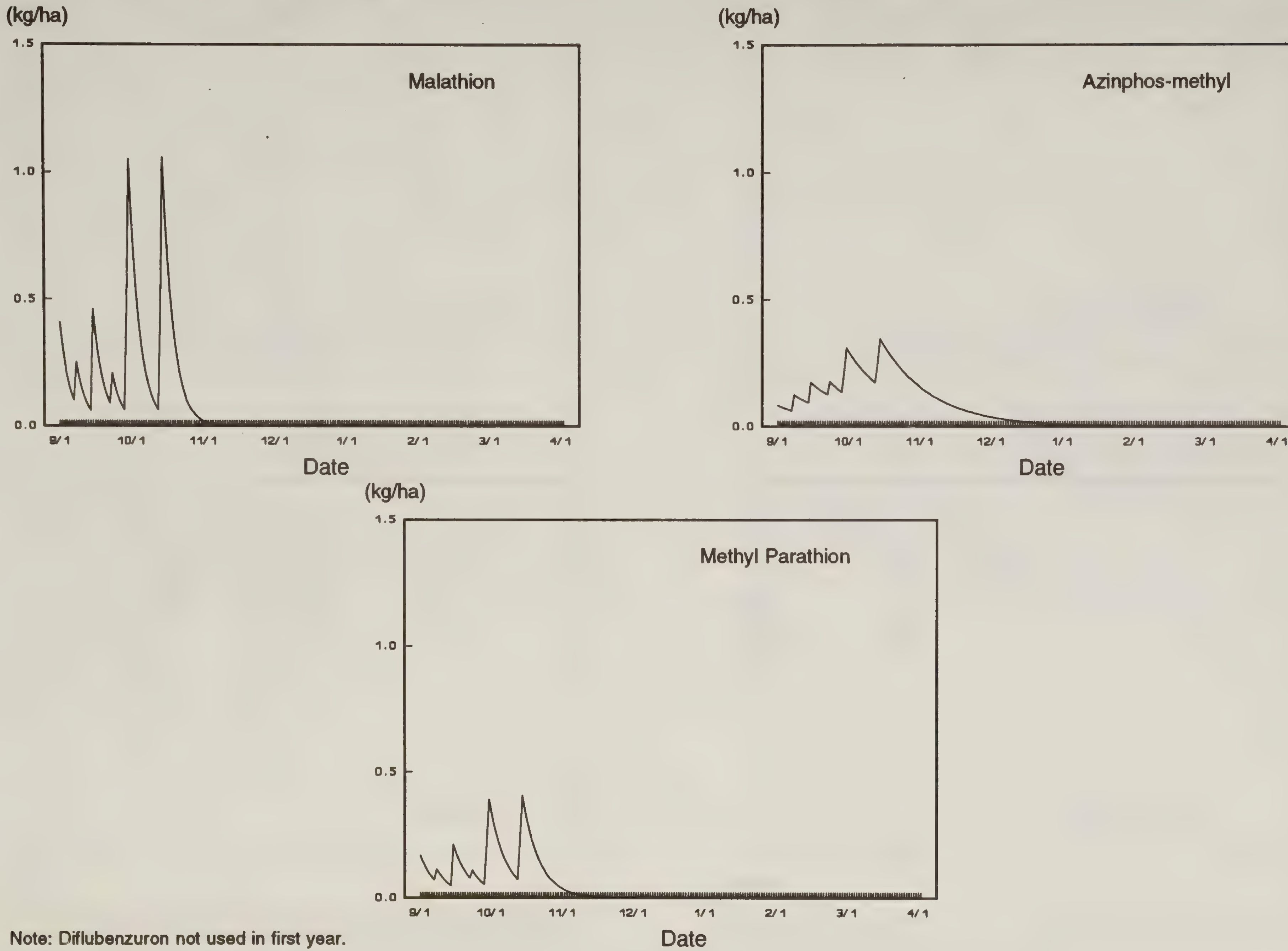


Figure B8-7. Estimated Pesticide Load in Alabama Decatur Silt Loam During the FIRST YEAR of an ERADICATION Program (shown in kg/ha)




Note: Diflubenzuron not used in first year.

Figure B8-8. Estimated Pesticide Load in Alabama Decatur Silt Loam During the SECOND YEAR of an ERADICATION Program (shown in kg/ha)

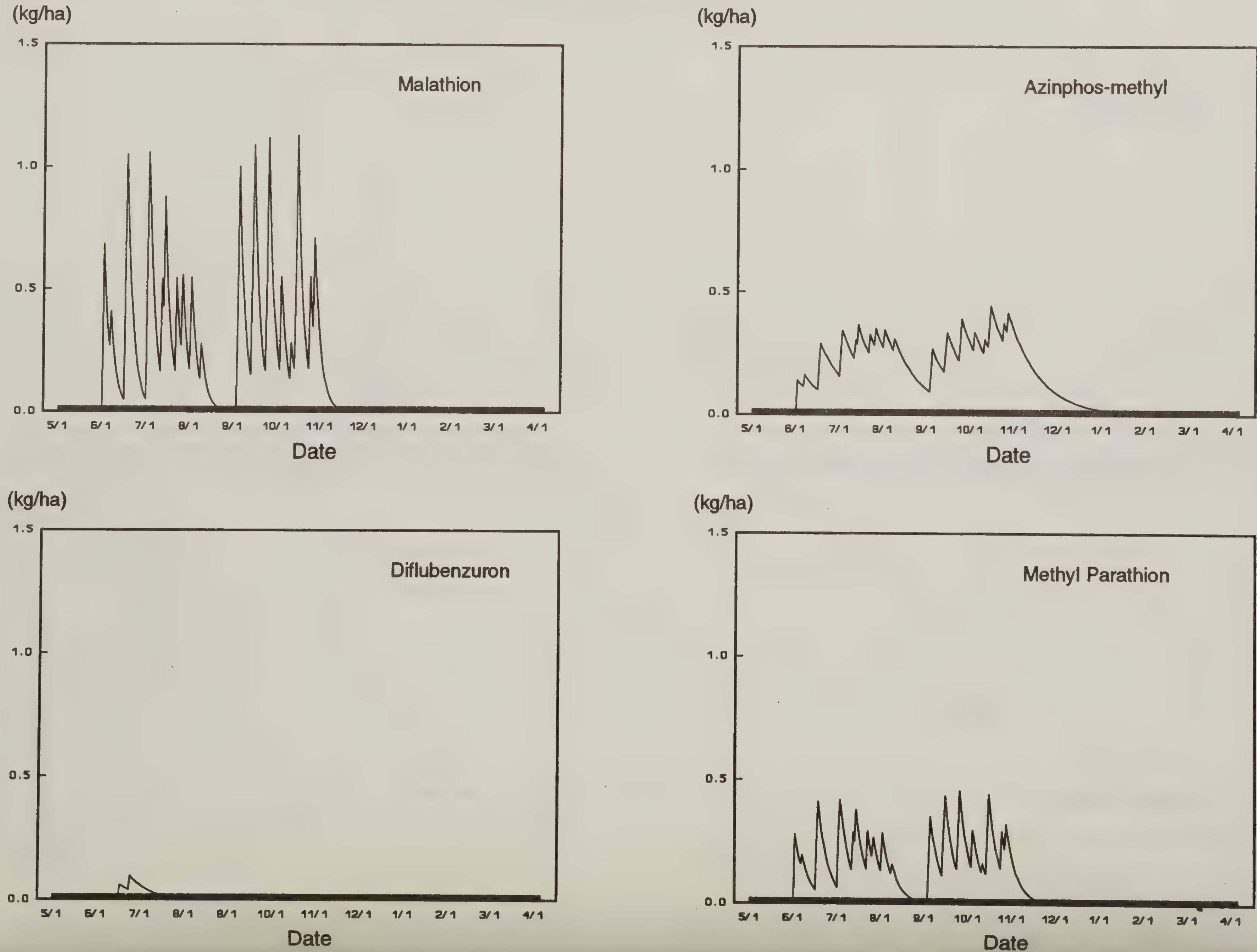


Figure B8-9. Estimated Pesticide Load in Alabama Decatur Silt Loam During the THIRD YEAR of an ERADICATION Program (shown in kg/ha)

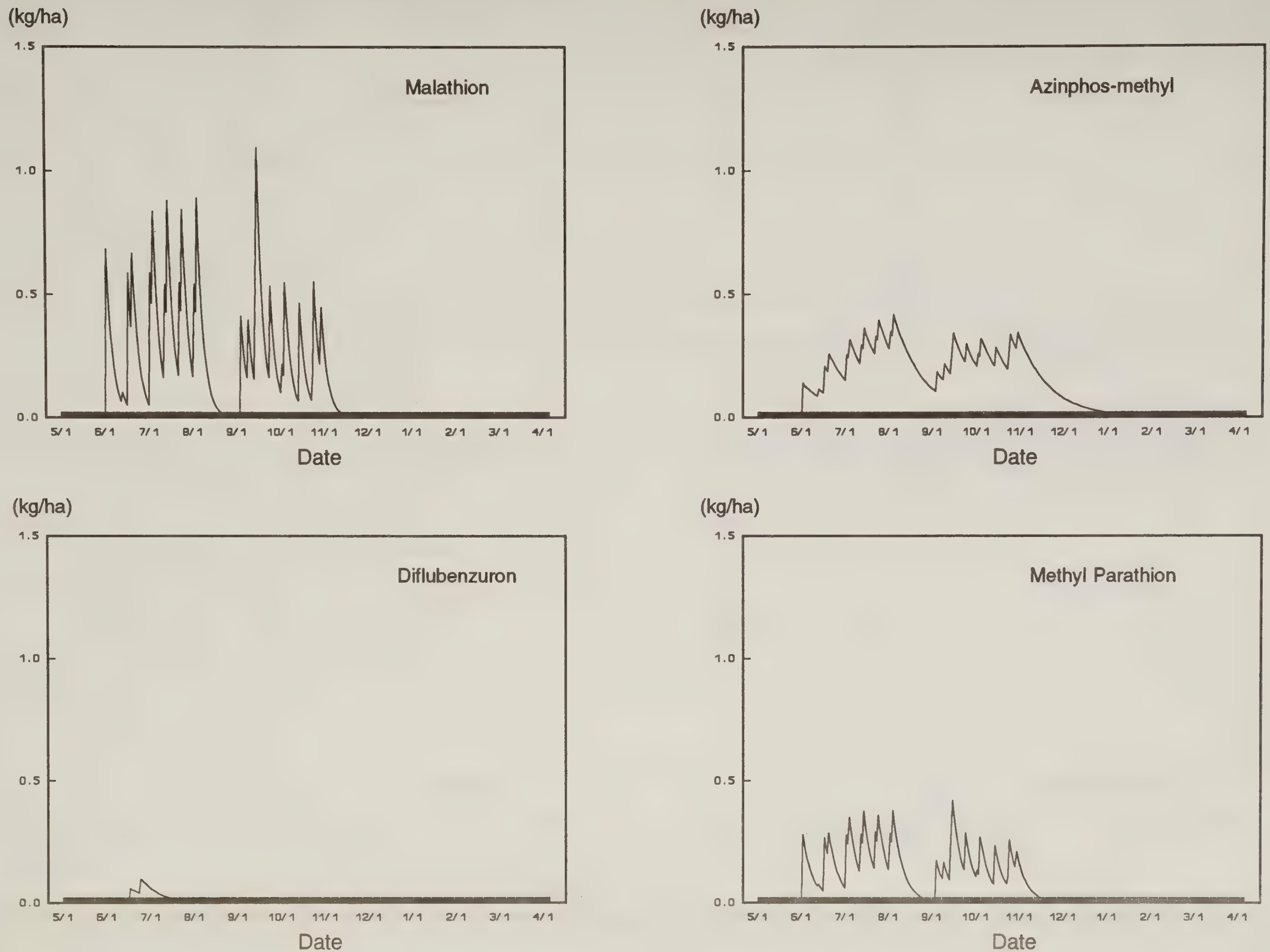
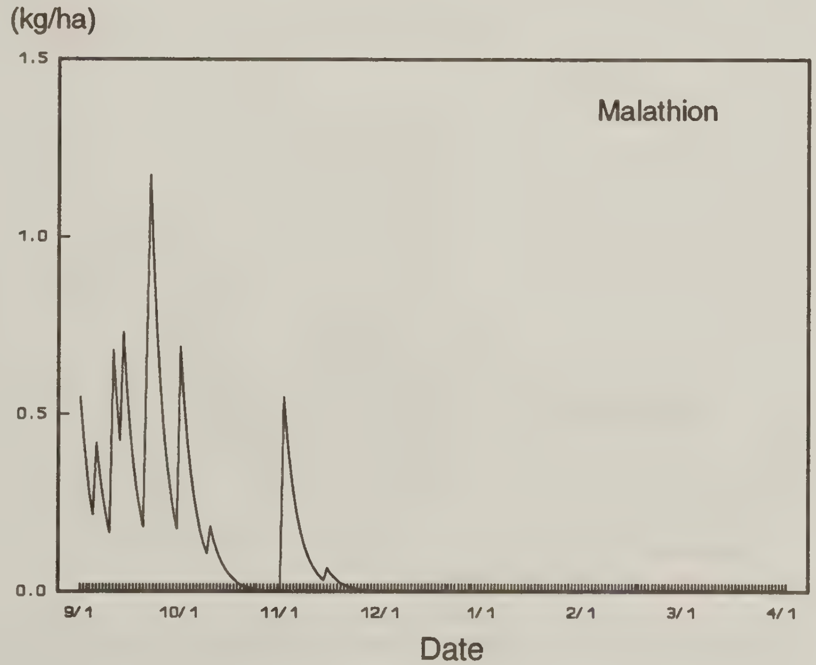
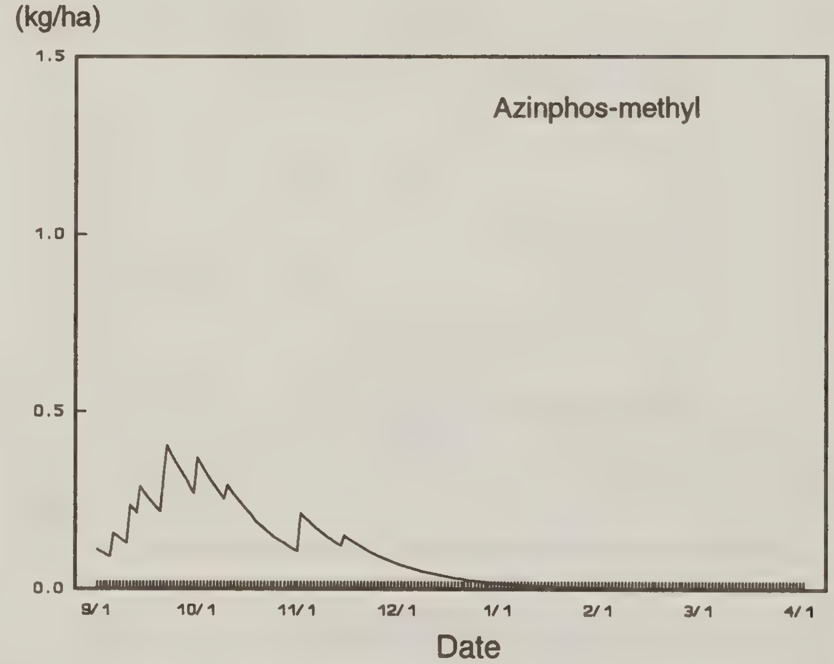
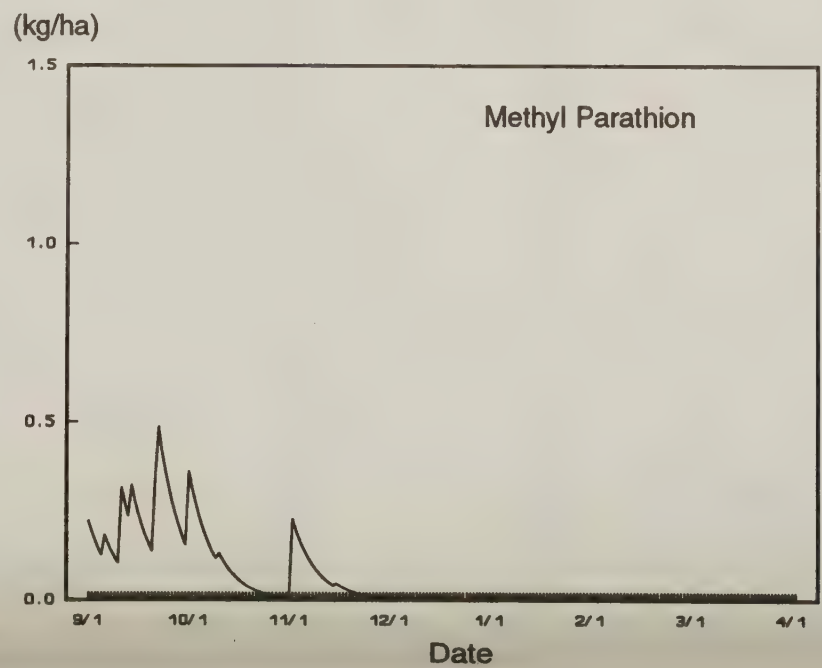


Figure B8-10. Estimated Pesticide Load in Texas Rolling Plains Abilene Clay Loam During the FIRST YEAR of an ERADICATION Program (shown in kg/ha)




Note: Diflubenzuron not used in first year.

**Figure B8-11. Estimated Pesticide Load in Texas Rolling Plains Abilene Clay Loam During the SECOND YEAR of an ERADICATION Program (shown in kg/ha)**

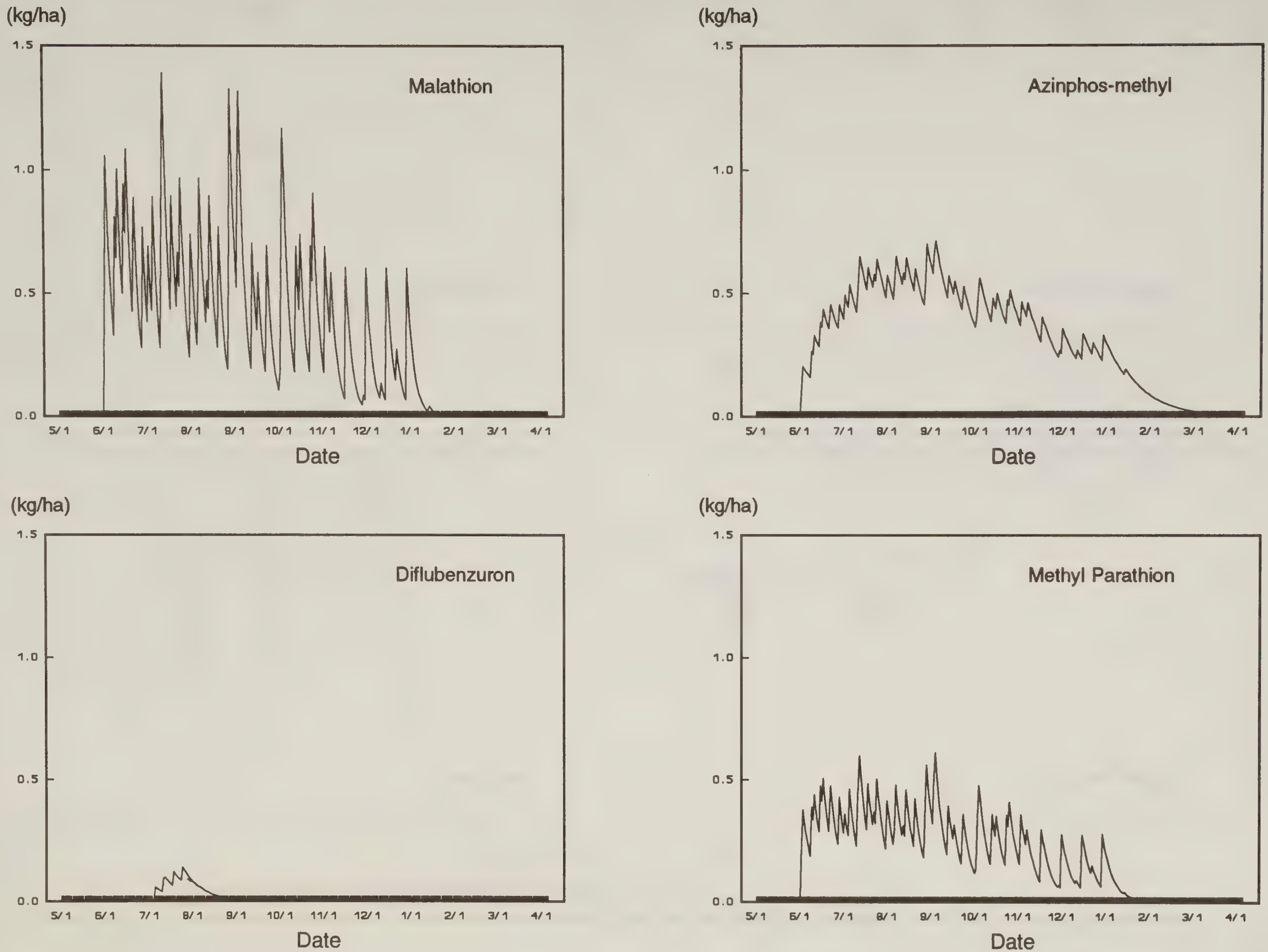


**Figure B8-12. Estimated Pesticide Load in Texas Rolling Plains Abilene Clay Loam During the THIRD YEAR of an ERADICATION Program (shown in kg/ha)**

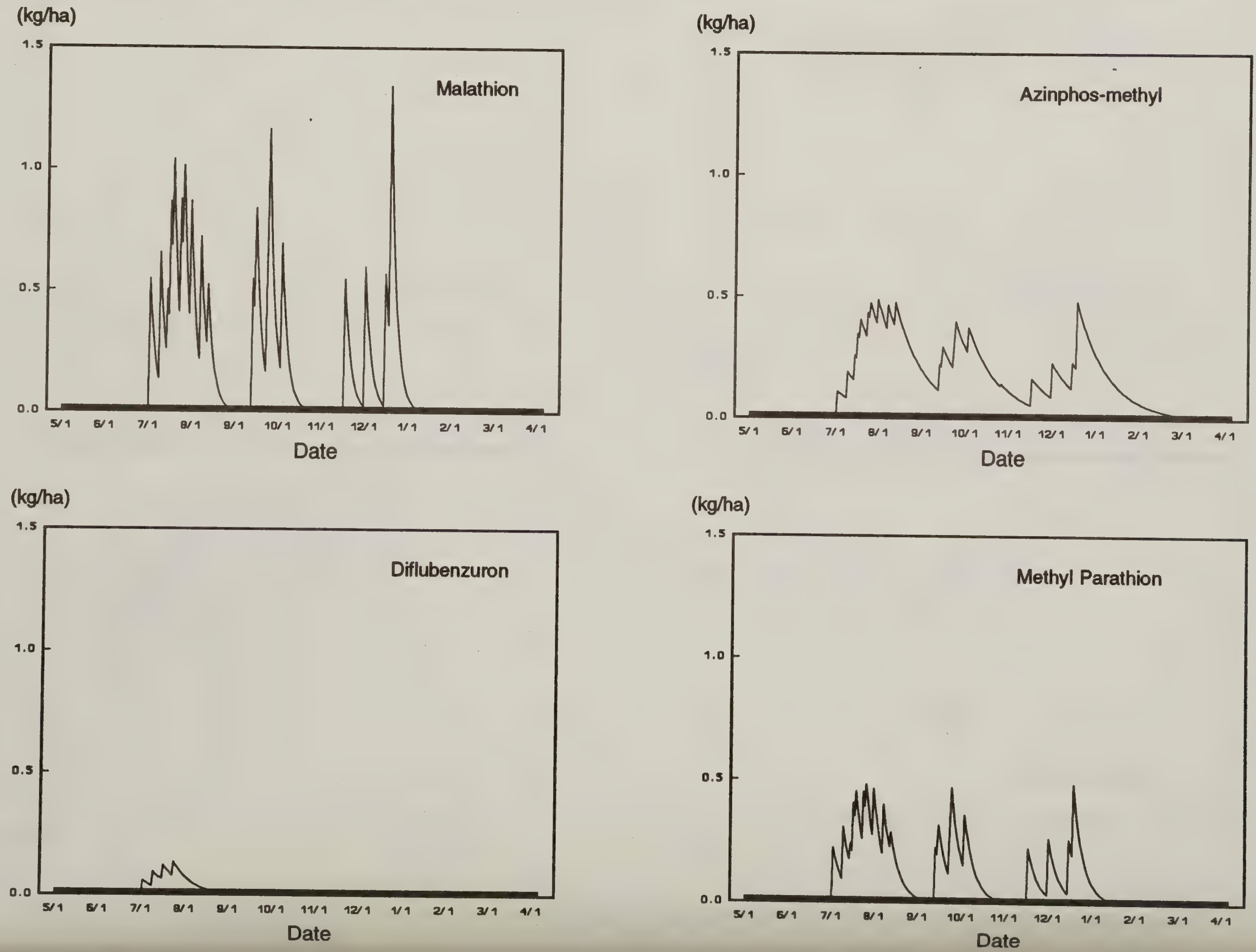


Figure B8-13. Estimated Pesticide Load in Mississippi Dubbs Very Fine Sandy Loam During the FIRST YEAR of a SUPPRESSION Program (shown in kg/ha)

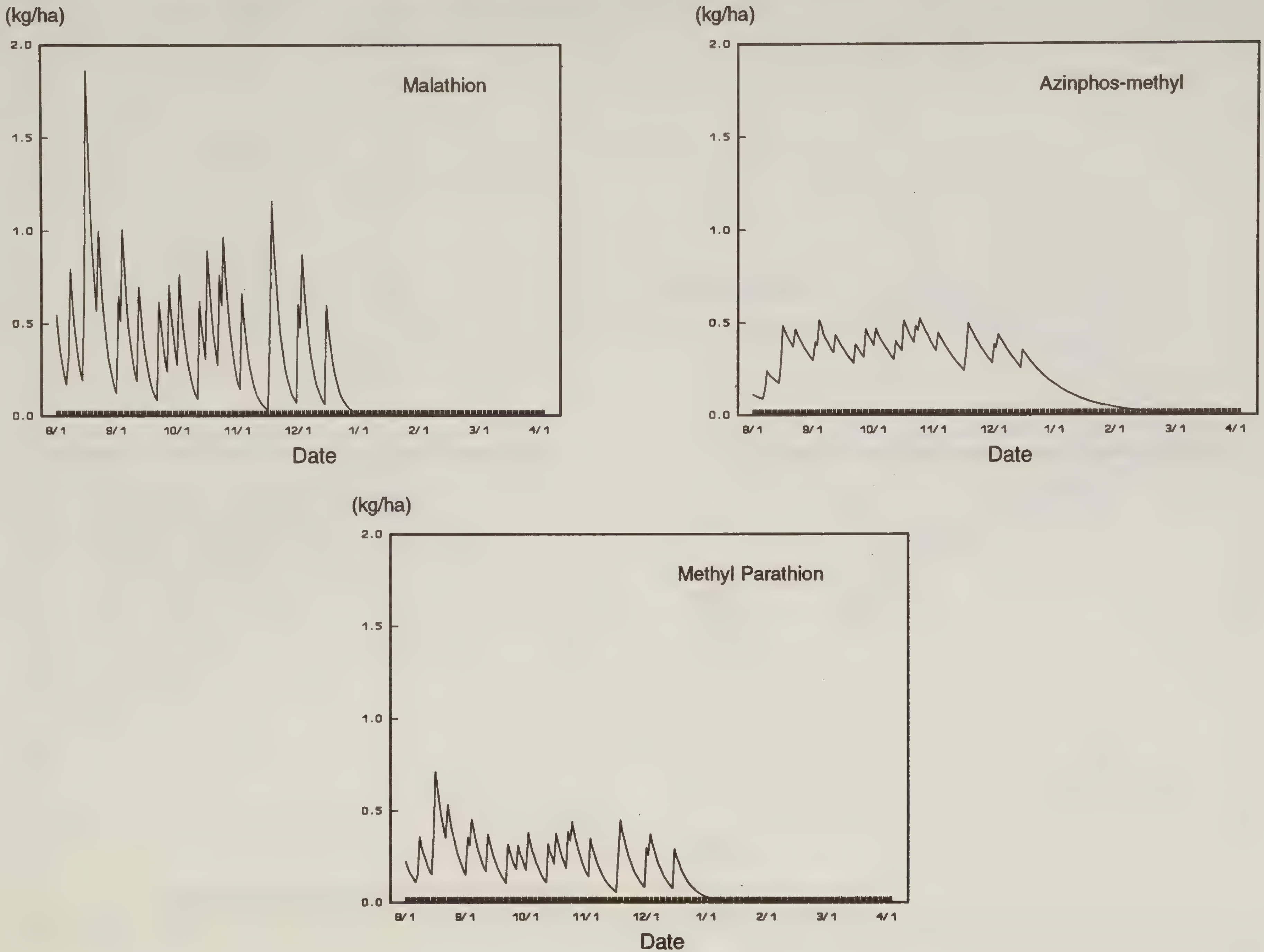


**Figure B8-14.** **Estimated Pesticide Load in Mississippi Dubbs Very Fine Sandy Loam During the SECOND YEAR of a SUPPRESSION Program (shown in kg/ha)**

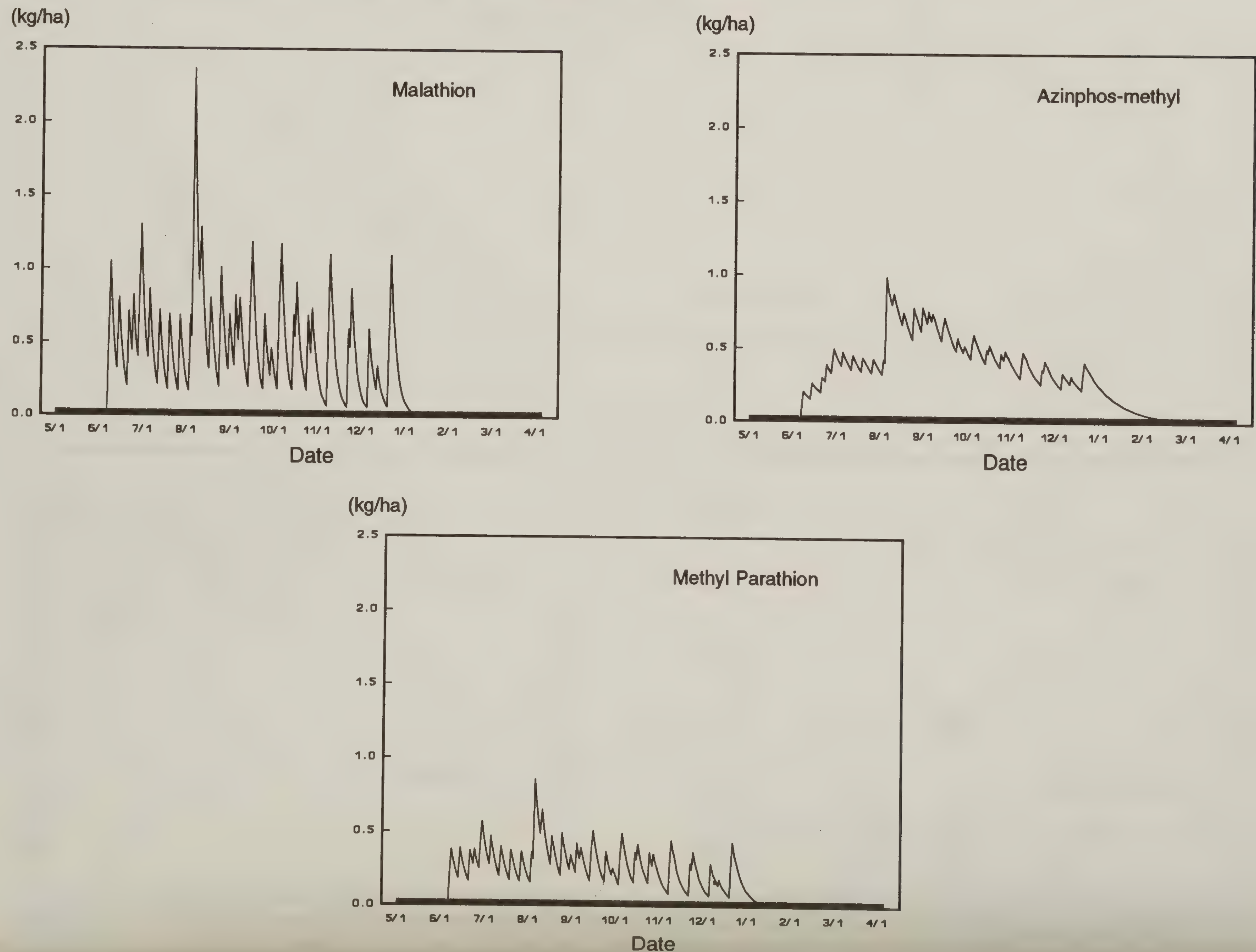


**Figure B8-15. Estimated Pesticide Load in Mississippi Dubbs Very Fine Sandy Loam During the THIRD YEAR of a SUPPRESSION Program (shown in kg/ha)**

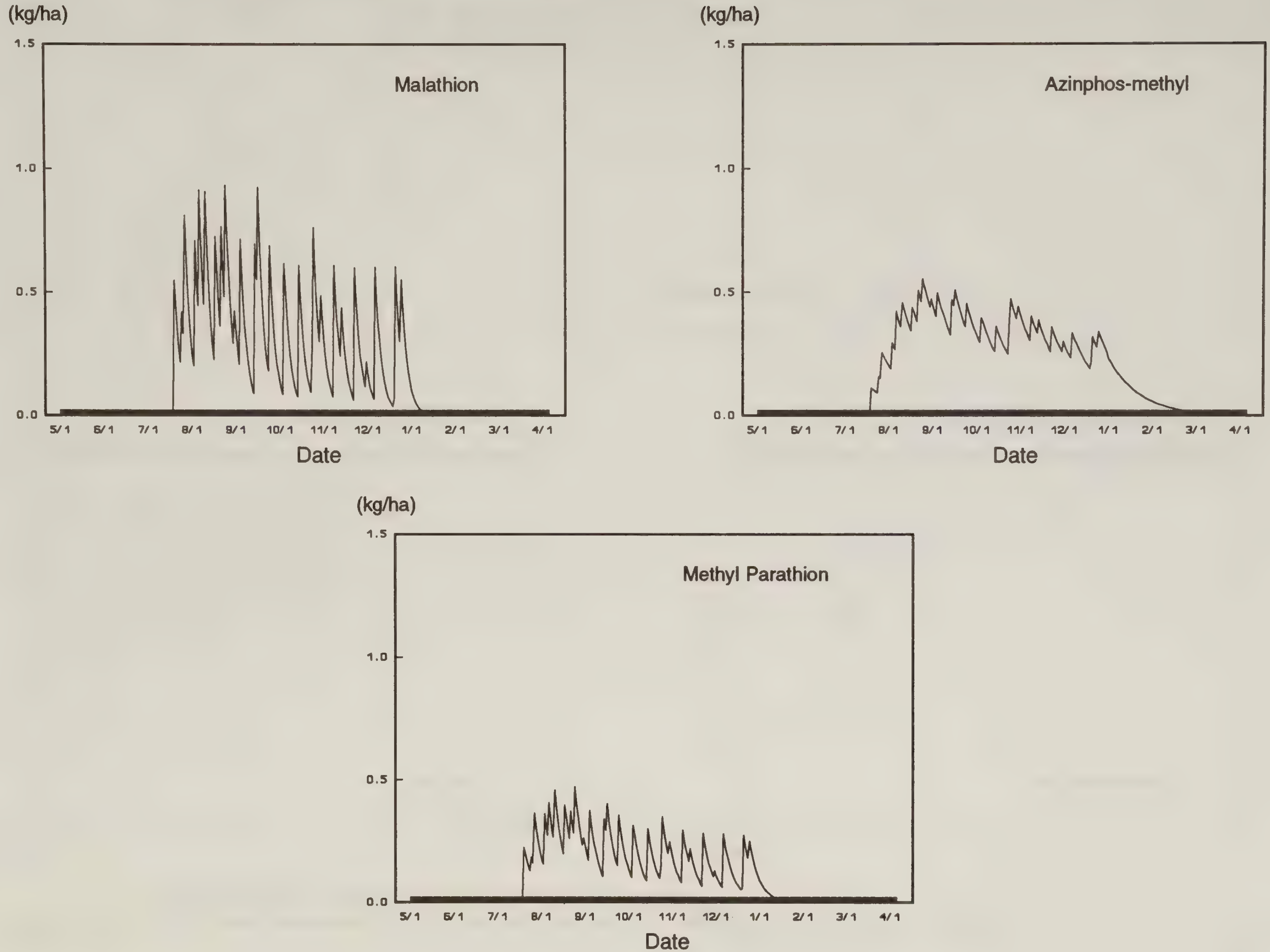


**Figure B8-16. Estimated Pesticide Load in Alabama Decatur Silt Loam During the FIRST YEAR of a SUPPRESSION Program (shown in kg/ha)**

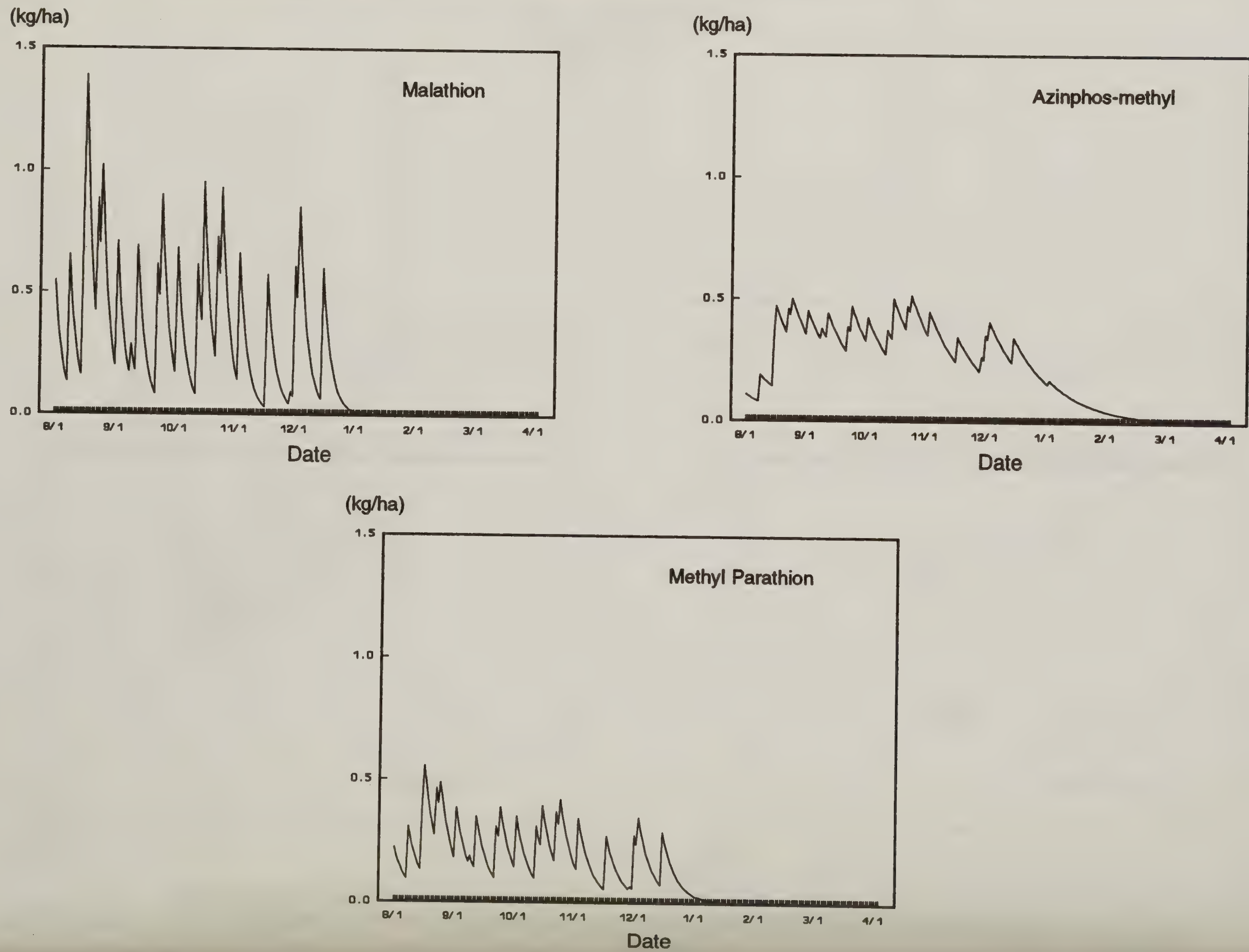


**Figure B8-17. Estimated Pesticide Load in Alabama Decatur Silt Loam During the SECOND YEAR of a SUPPRESSION Program (shown in kg/ha)**

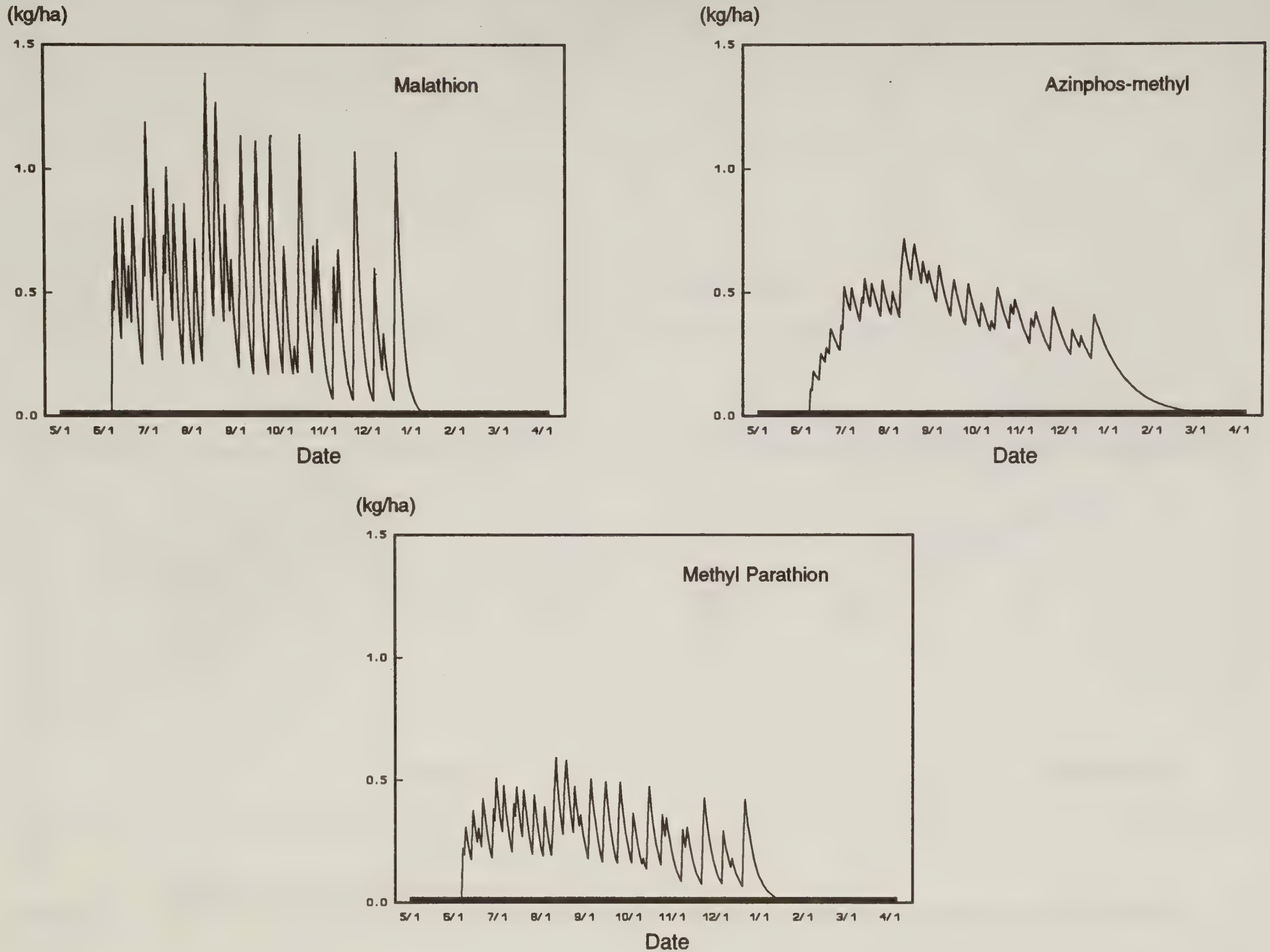


Figure B8-18. Estimated Pesticide Load in Alabama Decatur Silt Loam During the THIRD YEAR of a SUPPRESSION Program (shown in kg/ha)

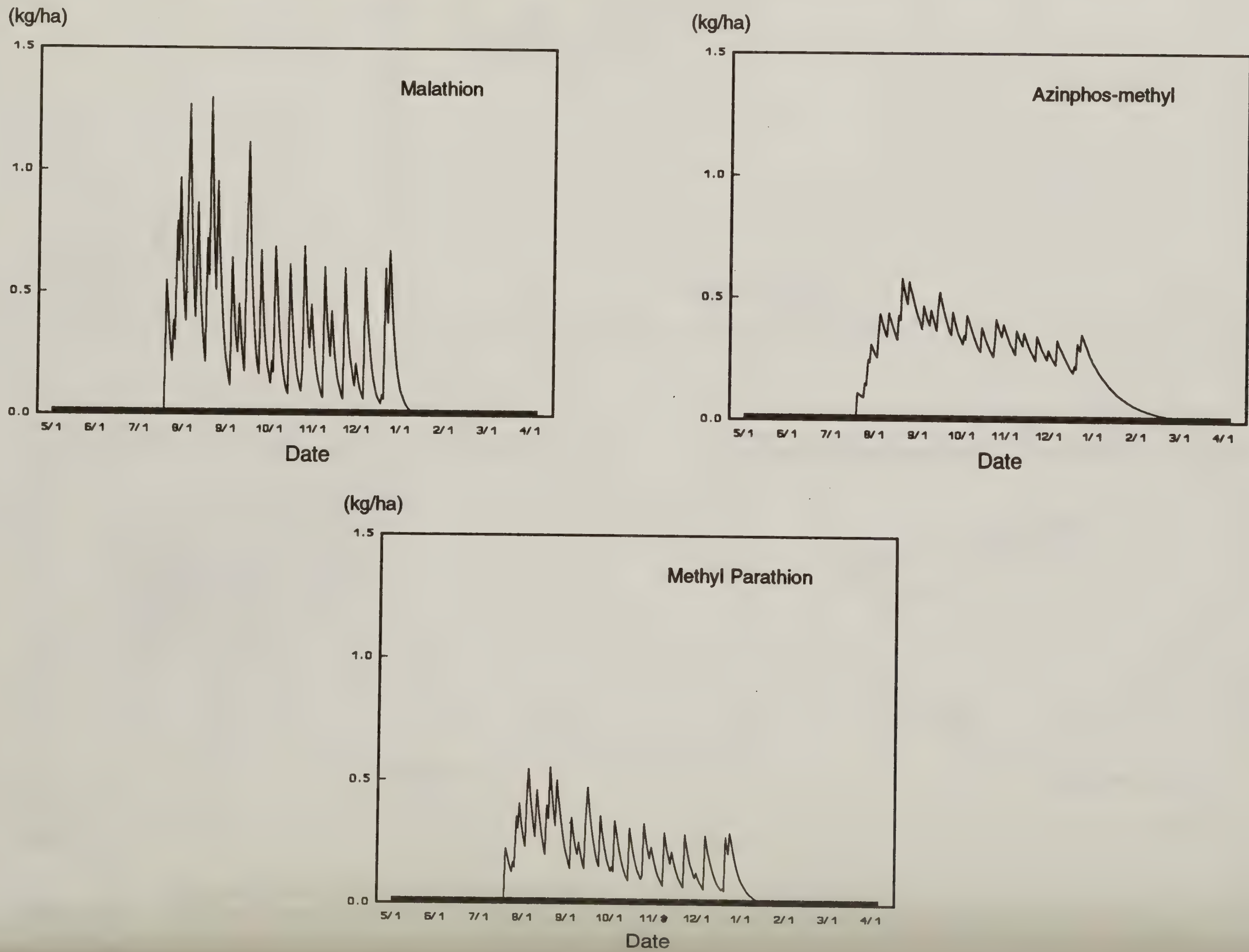


Figure B8-19. Estimated Pesticide Load in Texas Rolling Plains Abilene Clay Loam During the FIRST YEAR of a SUPPRESSION Program (shown in kg/ha)

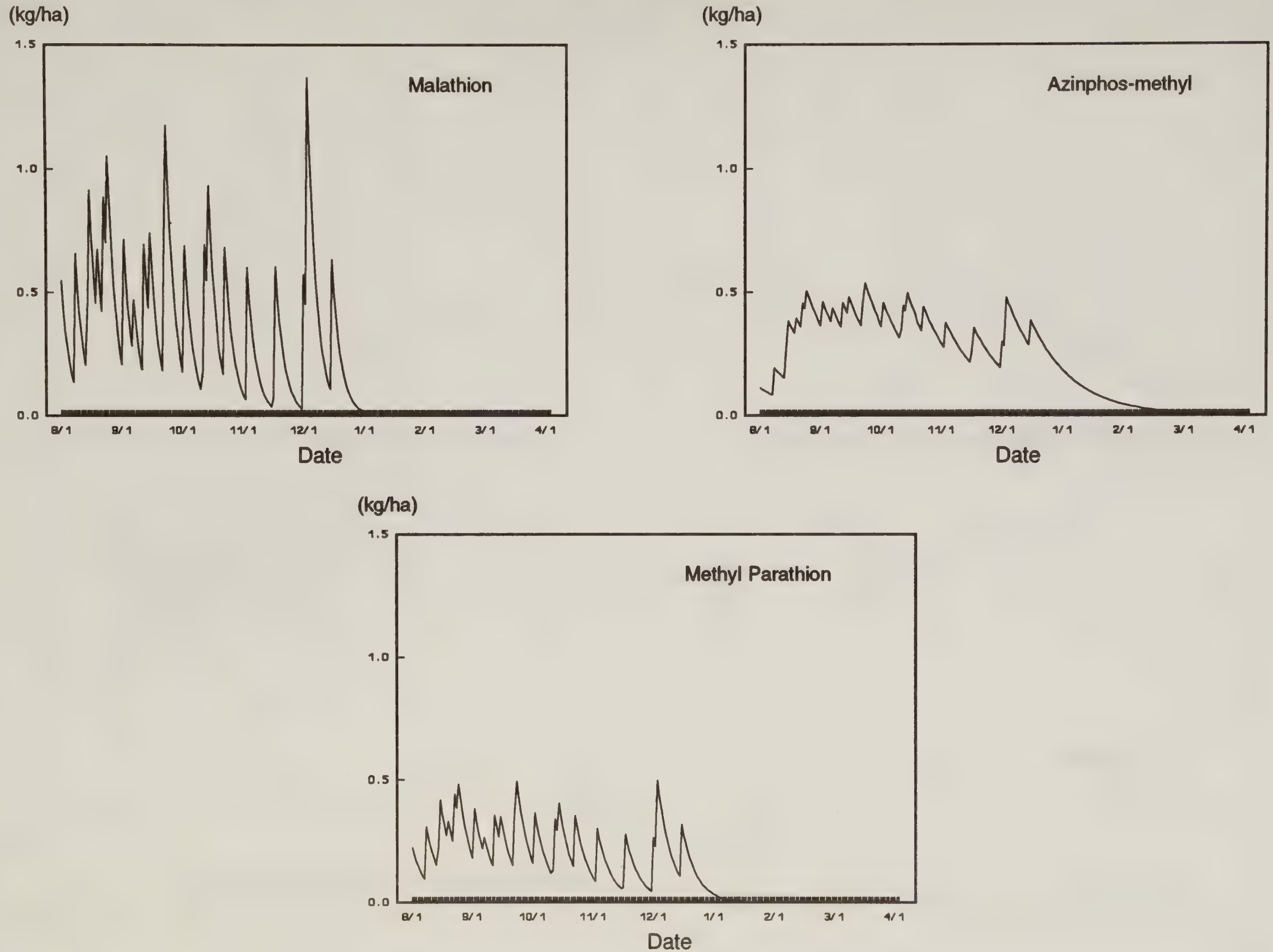


Figure B8-20. Estimated Pesticide Load in Texas Rolling Plains Abilene Clay Loam During the SECOND YEAR of a SUPPRESSION Program (shown in kg/ha)

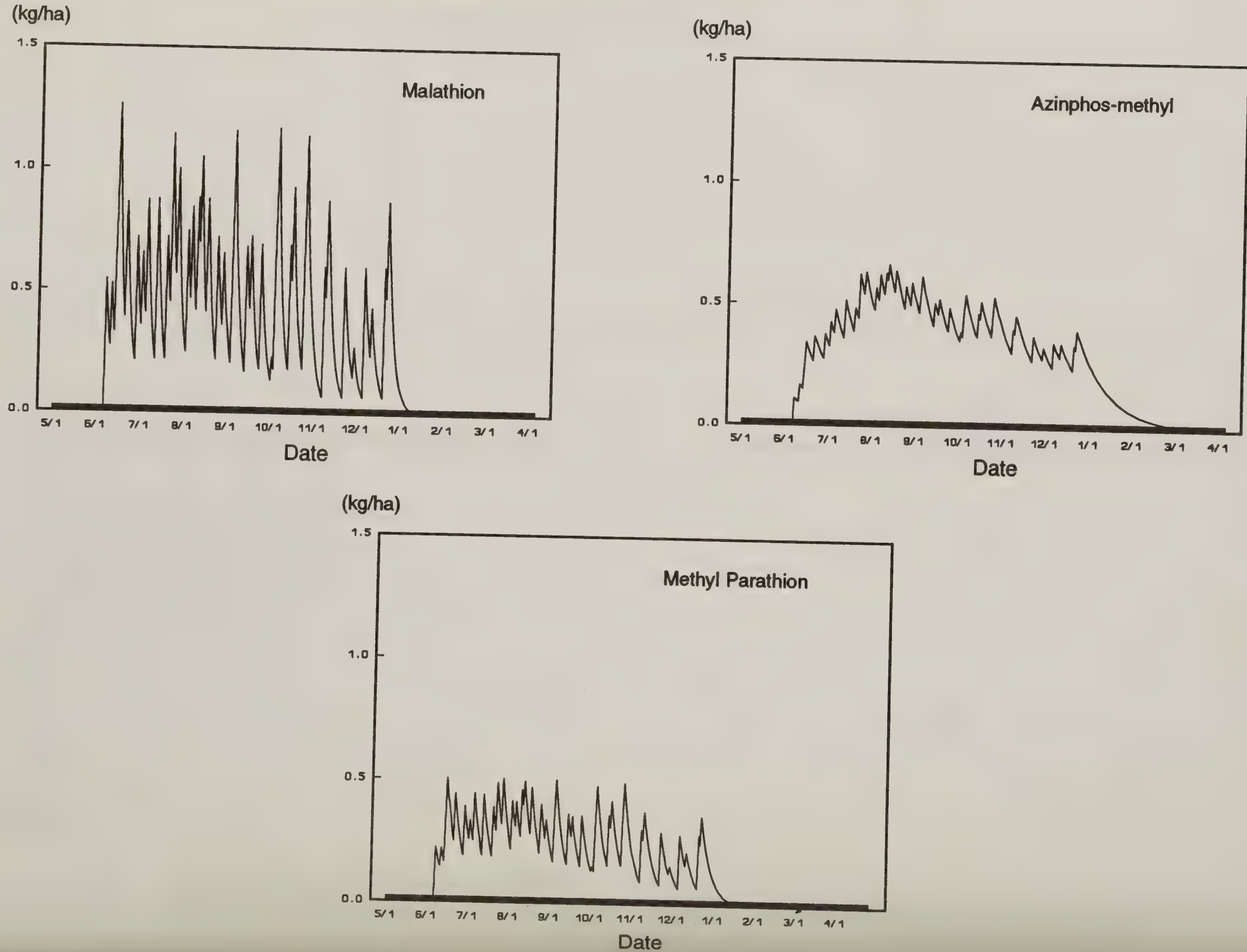
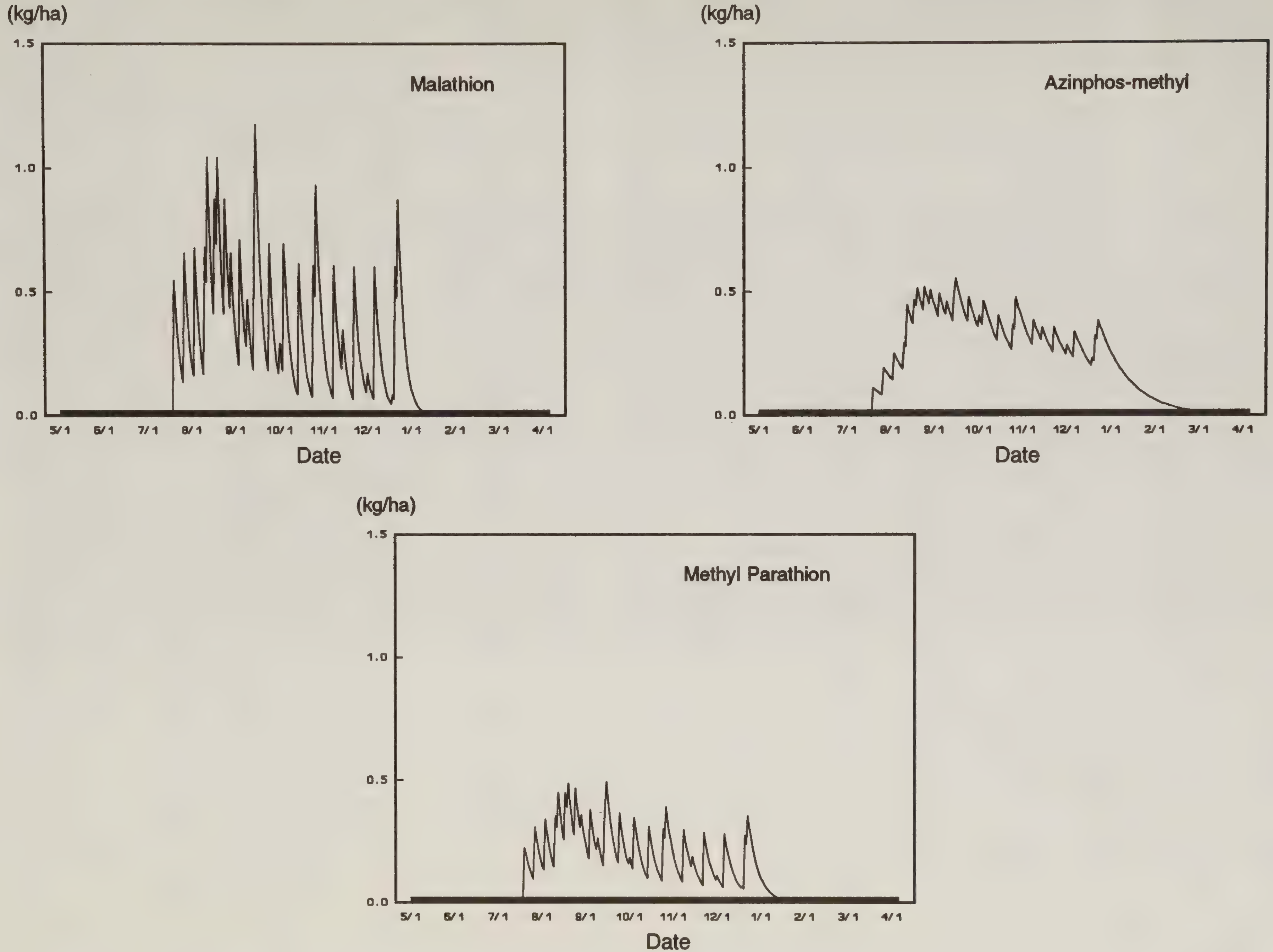


Figure B8-21. Estimated Pesticide Load in Texas Rolling Plains Abilene Clay Loam During the THIRD YEAR of a SUPPRESSION Program (kg/ha)



August. The residues should then decline over the fall and reach negligible levels by the middle of February of the following year. Methyl parathion residues peak in early July and early August at approximately 0.6 kg/ha. These residues should then decline over the fall and reach negligible levels by the middle of January of the following year.

The third year of the eradication program on Mississippi Dubbs very fine sandy loam is assumed to be at a reduced schedule. The results of the GLEAMS modeling for the final year of the program are presented in figure B8-6. Three major peaks in azinphos-methyl soil residues occur from early August to early December. The highest soil residues of approximately 0.7 kg/ha could occur in early August. Residues should reach negligible levels by the middle of February of the following year. Diflubenzuron may be used at low levels early in the season, resulting in a peak soil concentration of 0.1 kg/ha in late July and decreasing to negligible levels in the soil by the middle of August. Malathion residues should follow a similar pattern to the residues of azinphos-methyl. Four major peaks in soil concentrations could occur from early July to early December. The highest soil residues might occur in early August and reach a concentration of 1.8 kg/ha. Residues should reach negligible levels by early January of the following year. Methyl parathion residues should also follow a similar pattern to the residues from azinphos-methyl. The highest soil residues would likely occur in early August and reach a concentration of approximately 0.7 kg/ha. Residues should then decline to negligible levels by the middle of January of the following year.

***Alabama Decatur Silt Loam.*** During the first year of the program, treatments may be provided with azinphos-methyl, malathion, or methyl parathion. Again, diflubenzuron would not be used during the first year. Pesticide loadings to the soil during the first year, as determined by the GLEAMS model, are presented in figure B8-7. Azinphos-methyl residues could rise to a peak of 0.4 kg/ha by the end of October. The residue levels should gradually decrease after that time, with residue levels reaching negligible amounts by early January of the following year. Malathion levels should follow a similar pattern, reaching peaks in the beginning and middle of October of 0.1 kg/ha. Residues should then decline to negligible levels by the middle of November. Methyl parathion levels will also peak in the beginning and middle of October. These peaks show residue levels of 0.4 kg/ha. Residues should have declined to negligible levels by the middle of November.

During the second and third years of the program, in areas where soils such as the Decatur silt loam are present, application schedules are very similar. The results of the GLEAMS modeling to determine soil residues throughout the second and third years of the program are presented in figures B8-8 and B8-9, respectively. Because of changes in rainfall patterns between the second and third model years, maximum projected peaks for azinphos-methyl residues occur at different times.

In the second year, the peak occurs in the middle of November, while in the third year, the peak occurs in the beginning of August. However, soil residue levels during both peak times could reach about 0.4 kg/ha, and soil residues should decline to negligible levels in early January during both years. During both the second and third years of the program, diflubenzuron levels peak in late June after the second application and reach negligible levels by the middle of July. Malathion levels may peak at 1.2 kg/ha near the middle of August during both years. It should be noted that many peaks in residue levels during the second year of application may reach 1.2 kg/ha, as compared to the single peak that reaches that level during the third year of application. These differences are explained by the variation in rainfall in the data used in the model. Patterns similar to those seen in malathion residues can be seen in methyl parathion residue levels. Peak methyl parathion concentrations during both years reach 0.4 kg/ha and decline to negligible levels by the middle of November.

***Texas Rolling Plains Abilene Clay Loam.*** During the first year of the program, treatments may be provided with azinphos-methyl, malathion, or methyl parathion. Once again diflubenzuron would not be used during the first year. Pesticide loadings to the soil during the first year, as determined by the GLEAMS model, are presented in figure B8-10. When azinphos-methyl is applied to this soil type during the first year, soil residue levels could begin to rise after the first application in September and peak at the end of September at a load of approximately 0.4 kg/ha. Residues should decline after this time and reach negligible levels in late January. Malathion soil residue levels may peak at 1.2 kg/ha in late September. After the postharvest treatment in early November, residues should rapidly decline to negligible levels by the end of November. Methyl parathion residues are expected to follow approximately the same pattern as azinphos-methyl. Residues should reach a maximum soil loading of approximately 0.5 kg/ha in late September and should decline to negligible levels by late November.

After the first year of the program, the application schedule is predicted to be different, with increases in the number of applications for the year. Additionally, diflubenzuron may be applied in early season. Pesticide loadings to the Texas Rolling Plains Abilene clay loam soil during the second year are presented in figure B8-11. Azinphos-methyl residues are predicted to gradually increase in the soil because of the slow degradation of this pesticide. Azinphos-methyl residues should continue to rise and peak at a concentration of approximately 0.7 kg/ha in the beginning of September. The soil residue levels are then predicted to decline through the fall and winter and reach negligible levels by the middle of March.

During the second year, diflubenzuron may be applied in June and July. Low soil residues of diflubenzuron should peak in late July at approximately 0.15 kg/ha and decline to negligible levels by late August. Malathion residues should peak at levels of about 1.4 kg/ha in

the middle of July of the second year, with several similar peaks in early September. These residues should then decline over the fall and reach negligible levels by the middle of January of the following year. Methyl parathion residues could peak in the middle of July and the beginning of September at approximately 0.6 kg/ha. The residues should then decline over the fall and reach negligible levels by the end of January of the following year.

The third year of the eradication program for Abilene clay loam is assumed to be at a reduced schedule. The results of the GLEAMS modeling for the final year of the program are presented in figure B8-12. Three major peaks in azinphos-methyl soil residues could occur from early August to late December, with soil residue levels reaching approximately 0.5 kg/ha. Residues should then decline to negligible levels by the middle of March of the following year. Diflubenzuron may be used early in the season, resulting in a peak soil concentration of 0.1 kg/ha in late July and reaching negligible levels in the soil by the middle of August. Predicted malathion residues follow patterns similar to those of azinphos-methyl. Three major peaks in soil concentrations occur from late July to late December. The highest soil residues occur in late December and reach a concentration of approximately 1.4 kg/ha. Residues should decline to negligible levels by early January of the following year. Methyl parathion residues should follow a pattern similar to azinphos-methyl. The maximum soil concentrations are likely to be similar at all three peaks and are likely to reach concentrations of approximately 0.5 kg/ha. Residues should decline to negligible levels by the middle of January of the following year.

***Suppression Program.*** GLEAMS simulations were conducted with three soil types—Mississippi Dubbs very fine sandy loam, Alabama Decatur silt loam, and Texas Rolling Plains Abilene clay loam. Diflubenzuron was not modeled because it will not be used in the suppression program.

***Mississippi Dubbs Very Fine Sandy Loam.*** Figure B8-13 presents the results of the GLEAMS modeling to estimate residue levels during the first year of the suppression program. When compared to the results of the analysis of the first year of the eradication program, residue levels in the suppression program for all three insecticides should reach higher levels and are present for longer periods. Azinphos-methyl levels may peak at 0.5 kg/ha and reach negligible levels in late February. Malathion levels could peak at 1.9 kg/ha and reach negligible levels in early January. Methyl parathion levels could peak at 0.7 kg/ha and reach negligible levels in the middle of January.

Estimated residue levels in the soil during the second year of a suppression program in Mississippi Dubbs very fine sandy loam are presented in figure B8-14. Peak residue levels and disappearance rates match very closely to those seen in the second year of the eradication program. A peak in malathion soil residues of 2.4 kg/ha is seen in the middle of August in the suppression program. This peak is explained

by a large, naturally occurring storm event at that time. However, the magnitude of the rest of the concentration peaks of malathion residues in the suppression program match the magnitude of the peaks seen in the eradication program.

During the third year of the suppression program, residue levels should be similar to those seen in the third year of the eradication program. These estimated residue levels are presented in figure B8-15.

***Alabama Decatur Silt Loam.*** Figure B8-16 presents the results of the GLEAMS modeling to estimate residue levels during the first year of the suppression program. When compared to the results of the analysis of the first year of the eradication program, residue levels in the suppression program for all three insecticides should reach similar or higher levels and be present for longer periods. Azinphos-methyl levels during the suppression program should peak at 0.5 kg/ha and reach negligible levels in early March. Malathion levels could peak at 1.4 kg/ha and reach negligible levels in early January. It should be noted that although malathion residues peak at 1.4 kg/ha during late August, residues could be less than 1.0 kg/ha most of the time, similar to levels seen in the eradication program. Methyl parathion levels are predicted to peak at 0.6 kg/ha and reach negligible levels in the middle of January.

Estimated residue levels in the soil during the second and third years of a suppression program in Alabama Decatur silt loam are presented in figures B8-17 and B8-18, respectively. Peak residue levels during the suppression program may be slightly higher than those estimated for the eradication program for all three pesticides. During the suppression program, pesticide residues in the soil could remain for longer periods because of later applications.

***Texas Rolling Plains Abilene Clay Loam.*** Figure B8-19 presents the results of the GLEAMS modeling to estimate residue levels during the first year of the suppression program. When compared to the results of the analysis of the first year of the eradication program, residue levels in the suppression program for all three insecticides may reach slightly higher levels and be present for longer periods. Azinphos-methyl levels may peak at 0.5 kg/ha and reach negligible levels in early March. Malathion levels could peak at 1.4 kg/ha and reach negligible levels in early January. Methyl parathion levels may peak at 0.5 kg/ha and reach negligible levels in the middle of January.

Estimated residue levels in the soil during the second year of a suppression program in Texas Rolling Plains Abilene clay loam are presented in figure B8-20. Peak residue levels and disappearance rates match very closely to those seen in the second year of the eradication program.

During the third year of the suppression program, residue levels may be similar to those seen in the third year of the eradication program. These estimated residue levels are presented in figure B8-21.

## Potential to Leach into Groundwater

The GLEAM's model output also provides information on the potential of the four insecticides to leach into the groundwater at 10 representative site/soil combinations. The modeling results indicate that percolation through the soil (even during extreme storm events) is negligible. This means that even during the second year of the eradication program (with eight or more applications in a year) or in the suppression program (with a predicted maximum routine application of seven per year), groundwater should not be affected as a result of any boll weevil control alternative.

To further illustrate this point, table B8-14 presents the distribution of insecticide residues in the Mississippi Dubbs very fine sandy loam soil (one of the more porous soils) over a 3-year period under the suppression alternative. Although diflubenzuron may be applied during eradication treatments, soil residues were not detected by the end of each calendar year.

Table B8-14 illustrates that none of the insecticides reaches a depth of over 33 cm, or approximately 1 ft. Malathion generally reaches the highest concentrations in the soil, although it never reaches the groundwater in significant quantities. Azinphos-methyl, because it has a higher soil half-life and lower adsorption coefficient than the other insecticides evaluated, is predicted to migrate further than the other insecticides. As discussed previously, all of the insecticides readily degrade. They are also readily adsorbed to the soil. Based on these two processes and on the results of the GLEAMS modeling, none of the insecticides should reach the groundwater in any significant amounts.

Under certain conditions, it seems that minimal leaching of insecticides could occur in Arizona. The modeling scenarios evaluated the insecticide applications and rainfall patterns differently in Arizona than in the other representative sites. Irrigation is necessary to produce cotton in the arid environment of Arizona; therefore, according to communications with an Agricultural Research Station in Arizona irrigation flows of 17.78 cm (7 in) were added to the modeled cotton fields at scheduled intervals during the dry season (Bob Foster, Southwest Boll Weevil Eradication Program, Arizona). No migration of insecticides beyond the 76-cm depth was predicted during all storm or irrigation events for the Trix clay loam in Arizona under the eradication or suppression alternatives. After 2-year storms, the results for the Shontik sandy loam were similar to those of the Trix clay loam and other soils modeled in Texas, Alabama, Mississippi, and Georgia. However, subsequent to irrigation events on the Shontik sandy loam, with rainfall equivalent to 100-year storms, migration of azinphos-methyl and malathion beyond 1-m depth was predicted. The concentrations at these depths were

**Table B8-14. Distribution of Insecticide Residues (ppm) in Soil as a Function of Depth and Time (3 years) in Mississippi Dubbs Very Fine Sandy Loam Under the SUPPRESSION Alternative**

| Chemical | Residues at end of first calendar year | | | | |
|---|---|---|---|---|---|
| | Layer | | | | |
| | 0-1 cm | 1-16 cm | 16-33 cm | 33-50 cm | 50-67 cm |
| Malathion | 3.17 | 0.04 | 0.00 | 0.00 | 0.00 |
| Azinphos-methyl | 0.62 | 0.09 | 0.01 | 0.00 | 0.00 |
| Methyl parathion | 1.76 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Residues at end of second calendar year | | | | |
| | Layer | | | | |
| | 0-1 cm | 1-16 cm | 16-33 cm | 33-50 cm | 50-67 cm |
| Malathion | 0.87 | 0.03 | 0.00 | 0.00 | 0.00 |
| Azinphos-methyl | 0.38 | 0.08 | 0.01 | 0.00 | 0.00 |
| Methyl parathion | 0.95 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Residues at end of third calendar year | | | | |
| | Layer | | | | |
| | 0-1 cm | 1-16 cm | 16-33 cm | 33-50 cm | 50-67 cm |
| Malathion | 0.23 | 0.02 | 0.00 | 0.00 | 0.00 |
| Azinphos-methyl | 0.13 | 0.07 | 0.01 | 0.00 | 0.00 |
| Methyl parathion | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 |

Note: Diflubenzuron will not used as a part of the suppression program.

estimated at 1 to 0.1 ppb. Because the water table in this region is often at depths exceeding 30 m, the insecticides applied under the boll weevil control program are not predicted to reach groundwater.

### Summary of GLEAMS Results

The results of the GLEAMS analysis indicate that for all chemicals and all representative soil types, no cumulative buildup of insecticide residues in soil is expected. In each succeeding year of the eradication program, the maximum buildup of residues decreases, and significant residues exist for much shorter periods. The results also show that most of the insecticide residues are lost through surface-water runoff (little insecticide is expected to reach groundwater). The amount of runoff depends on the time between the last application and the storm, the antecedent moisture conditions, and the amount of vegetative cover. All other factors being held constant, the potential for causing degradation of surface-water bodies is approximately the same under the eradication and suppression program alternatives.

## The EXAMS Model

The EXposure Analysis Modeling System (EXAMS) (Burns et al., 1982) model was used to estimate the effects of agricultural runoff containing insecticides considered for use in this EIS. This model provides information on the transport and fate of chemical pollutants in surface water.

### Background

The simulation of insecticide concentrations for representative river basins was accomplished with EXAMS II, the Exposure Analysis Modeling System developed at the Athens Environmental Research Laboratory of the U.S. Environmental Protection Agency (Burns et al., 1982; Burns and Cline, 1985). EXAMS II is an interactive program that allows a user to specify and store the properties of chemicals and the potentially affected environment.

EXAMS II is a set of mathematical models that simulates the most important factors that contribute to the degradation and transport of a chemical in an aquatic environment. A variety of biological, chemical, and physical factors are considered. The program requires input of the following four types of variables: (1) ecosystem variables; (2) chemical variables; (3) chemical application loading variables; and (4) model operation variables (for example, steady-state vs. time-varying simulation).

The aquatic environments used by EXAMS II are represented as sets of N compartments. Aquatic compartments are assigned odd numbers, and benthic (sediment) compartments are assigned even numbers. The relationships of one compartment to another are represented within the system, but variations within a given compartment are not recognized. EXAMS II assumes that each compartment is well mixed. Changes in levels of the chemical within each compartment are represented by a set of differential equations based on the conservation of mass (for accounting of the chemical only) that represent (1) loading of the chemical from external sources, (2) transport processes bringing the chemical from other compartments or exporting it to other compartments or out of the

system, and (3) transformation processes within the compartment that cause the compound to degrade to offspring products.

The unit process models that describe the dynamic behavior of the chemical are generally second order models in the sense that their rates depend on interactions between the chemistry of the compound and the environmental characteristics that control its behavior. However, the characteristics of the environment are assumed to be static during the course of a simulation so that the transformation and transport processes can be described by pseudo first-order rate constants. For this study, the chemical inputs and the environmental characteristics were considered to be at a steady state.

EXAMS II contains many optional inputs and alternative component models to represent the factors causing degradation. The data needed to use some of the component models are not available, and some of the components are not relevant to the chemicals and environments under study. For the purposes of this study, the system was intended to represent the essential aspects of the environments and processes considered, but unnecessary complication was avoided in the interest of clarity and economy.

**Ecosystem Definition**

EXAMS II requires a three-dimensional definition of the environment to be modeled. The environments selected for modeling included the Red River Basin in Texas and Oklahoma, the Tennessee River Basin in Alabama and Tennessee, the Sunflower River Basin in Mississippi, the Gila River Basin in Arizona, and the Flint River Basin in Georgia. These areas were chosen to represent a diverse assortment of Cotton Belt environments.

The length of the main trunk of each basin was determined by evaluating river basin maps (USDA, 1970) and streamflow records (USGS Water Resources Data Reports). Large dams along the main trunk, as in the Tennessee and Gila River Basins, served as convenient endpoints to define the boundaries of the segment to be modeled. Water monitoring stations defined the segment boundaries of the Sunflower, Red, and Flint River Basins. The trunk of the river was divided into 16 compartments of equivalent length, the maximum number allowed in the microcomputer version of EXAMS II. Aquatic compartments were assigned the odd numbers from 1 to 31, and sediment compartments were assigned the even numbers.

The geometries of the river segments were computed using river basin maps (USDA, 1970), topographic maps prepared by the U.S. Geological Survey (USGS), and width measurements with area estimations at USGS water monitoring stations. Precipitation records from each river basin area were consulted to determine the dates when 2-year storms occurred. Streamflow data from monitoring stations along the main trunk were correlated with the precipitation data to determine the resultant streamflow, which was used with the dimension measurements to establish the average width, area, and depth of the river after

2-year storms. Only average flow conditions, however, were used to model the Tennessee River Basin because it has large dammed reservoirs, and the storm discharge recorded at downstream monitoring stations was not significantly greater than the discharge upstream. It was assumed that the average depth was equivalent to the estimated area divided by the measured width.

EXAMS II requires streamflow data for inputs into the initial compartment and any additional flows into successive compartments. The model then computes a volumetric balance of the flows for each compartment. Because precipitation events are sometimes localized in parts of the basin, the recorded streamflow data did not always balance volumetrically (downstream values were not significantly higher than upstream values). To account for variabilities of storm extent and location, the recorded streamflow entering the initial compartment, as determined from monitoring data, was subtracted from the streamflow leaving the final compartment to establish the total flow in the system. Each river basin was divided into 16 drainage areas defining the compartment boundaries. A flow into each compartment was calculated to estimate the contribution of tributaries, direct rainfall, groundwater flow, and runoff. The amount of water added to the system between its start and endpoints was distributed among compartments according to the relative size of the drainage area. Monitoring data on tributaries and the trunk stream were used as a guide to apportion the flow added into the basin. Because flow in the Gila River decreased dramatically near Phoenix (zero flow in a tributary after a 2-year storm event) and was irregular in other areas, this basin was modeled by assuming that each segment had the same contribution from overland, tributary, and groundwater flow. Although portions of the Gila River Basin north of Phoenix produced cotton, they were not modeled because no flow was observed in the Salt River (a tributary of the Gila). Because no flow was recorded in the last several years, insecticides would not be transported from the Salt to the Gila. These assumptions were necessary to be consistent with an assumption made concerning pesticide loadings (as discussed in the pesticide loading section of this chapter).

Biological input parameters are also included in EXAMS II. Nominal biomasses were included in each compartment to observe any bioaccumulation. The insecticides scheduled for use in the cooperative control program degrade in water primarily by biological processes and hydrolysis.

**Pesticide Characteristics**

The physical and chemical parameters used as inputs to EXAMS II are shown in table B8-15. Although many other characteristics may be used in the modeling process, the parameters shown in the table are used by the model to calculate Henry's law constant and other chemical variables. The data shown for methyl parathion were provided in the EXAMS II program files, although certain data (vapor pressure, for example) do not correspond to the values provided in table B8-5. The

Table B8-15. EXAMS II Physical and Chemical Input Parameters

| Chemical | Molecular weight (g/mole) | Vapor pressure (torr) | Organic carbon fraction KOC (mg/kg/mg/L) | Solubility (units/hour) | Degradation rate constant (units/hour) |
|---|---|---|---|---|---|
| Malathion | 330 | 0.000125 | 1,800 | 145 | 0.00412 |
| Azinphos-methyl | 317 | 0.0000000075 | 700 | 29 | 0.000960 |
| Diflubenzuron | 311 | 0.000001 | 6,700 | 0.20 | 0.0204 |
| Methyl parathion | 277 | 14.4 | 14,000 | 50 | 13.7 |

vaporization predicted by the model was not sensitive to the range of vapor pressures evaluated.

**Pesticide Loadings**

Once the EXAMS environments have been created for the individual river basins and the chemistry parameters have been defined, the amount of insecticides introduced to the system must be determined. The loadings were estimated by using the runoff values calculated by GLEAMS and determining the acreage of treated cotton fields in counties within the drainage basin.

A number of assumptions were required to estimate the insecticide loadings. Streamflow and precipitation data illustrated roughly a 7-day cycle for all river basins; after the storm, streamflow peaked about 3 days after the storm and receded to prestorm levels by about day 7. It was assumed that the insecticide loadings take place in equivalent hourly pulses for 7 days.

For the modeling of all insecticides in the Red, Sunflower, Gila, and Flint Rivers and the modeling of azinphos-methyl in the Tennessee River, it was assumed that the entire basin was sprayed at the same time. In reality, several days to more than a week may be required to treat all the cotton acreage within each river basin. Within a week, some of the insecticides would have degraded by half of their original concentration before other areas of the basin would be sprayed. This assumption would overstate the predicted concentrations within the rivers in the basin on the average, but the exposure analysis is based on the maximum concentration in any particular compartment of the modeled basin. It is realistic to assume that a portion of the basin would be treated at a maximum frequency and would have a 2-year storm cause runoff into a particular portion of the main trunk of the river basin.

In appendix I—Implementation of the Program in Alabama—revisions were made for diflubenzuron, malathion, and methyl parathion in the GLEAMS modeling and subsequently in the EXAMS II modeling for the Tennessee River Basin. Those revisions have been incorporated into this document and include two components. First, the application schedules were changed to better reflect actual program needs in the Tennessee River Basin. Second, it was assumed that the Tennessee River Basin would take 3 days to spray during the most intense application periods. It was further assumed that the applications would take place on 3 consecutive days, with the last day of applications 2 days before the storm event.

In addition, in the draft EIS, the malathion soil half-life used for all modeling was 7 days. After more detailed research into the conditions under which various half-lives are measured and the range of half-lives reported, it was decided that a malathion half-life of 3 days was more realistic. The GLEAMS modeling for all soil types was revised to include the new half-life. In addition, the EXAMS II modeling for the

Tennessee River was revised to include the new GLEAMS output. The EXAMS II modeling for all other rivers was not revised.

The combination of all the above changes in the analysis of malathion in the Tennessee River caused a 37-percent reduction in the malathion water concentrations from the original analysis. Greater reductions were seen in the diflubenzuron and methyl parathion water concentrations.

The river basins modeled were quite extensive, with tributary lengths in excess of 100 miles. This analysis conservatively assumed that the insecticides applied in the furthest reaches of a river basin would reach the main trunk without being degraded; realistically, some degradation would occur. As previously discussed, the Gila River Basin flows were assumed to be equivalent by compartment. If actual flows had been used, the assumption of no degradation along tributaries would have caused unrealistically high concentrations of insecticide in the Gila River. The distribution of cotton fields within individual counties was not known for all the river basins. For predicting the contribution of insecticide to each compartment of the main trunk, it was assumed that the cotton acreage was randomly distributed throughout each county and that the proportion of the county within the river basin, as determined from matrix counting, was equivalent to the proportion of the county's acreage susceptible to runoff in that particular basin.

Runoff from more than one soil type was modeled in the Gila, Sunflower, and Red River Basins. It was assumed that each soil type supported half of the cotton acreage in each basin. Consequently, the estimated loadings per acre for both soil types were combined and an average value taken to represent the loading per acre for the entire basin.

A cotton-producing county within a river basin may sometimes have runoff going to more than one compartment. Each river basin was divided into subbasins that ideally drained into separate aqueous compartments. The fraction of each different subbasin within a county was visually estimated by matrix counting. Computer programs were developed to calculate the cotton acreage by county within a particular river basin and to multiply the acreage by the mass loading per acre of each insecticide. The resultant total loadings per subbasin within each county were aggregated by compartment and divided by 168 to emulate an hourly loading interval over 7 days.

## Model Operation

The insecticide chemistry variables, river dimensions, compartmental stormflows, biological variables, and predicted insecticide loadings were used to run EXAMS II. The model has three modes of operation: (1) steady-state loadings; (2) steady-state and/or pulse loadings over a defined interval with user interaction; and (3) steady-state and/or pulse loadings over a minimum period of 1 year with no defined maximum. The second mode was used in this analysis because of its inherent flexibility.

## EXAMS II Simulations

The EXAMS II modeling estimated the riverine concentration of insecticides derived from surface-water runoff from treated cotton fields under the proposed boll weevil suppression and eradication programs. GLEAMS predicted no leaching, and thus no groundwater transport, of insecticides from treated cotton fields. The only component of insecticide contribution in EXAMS II was from surface-water flow. Tables B8-16 through B8-20 illustrate the maximum predicted river concentrations in any compartment after 7 days of a 2-year storm for the five river basins modeled. Because a steady-state loading of the insecticides was assumed, the highest concentrations are found on day 7 of the precipitation event. However, because of the rapid degradation rates of the insecticides, the concentrations at day 7 are within 6 percent of those on day 6.

The average concentration of the insecticides in each river was predicted to be approximately three times less than the maximum concentrations reported in tables B8-16 through B8-20. For each river basin, the predicted riverine concentrations of insecticides were similar for the eradication and suppression programs. The highest concentrations calculated were for malathion use under the eradication program in the Red River Basin. These concentrations were about an order of magnitude higher than concentrations predicted for the Sunflower and Flint River Basins, and about two orders of magnitude higher than the concentrations estimated for the Gila and Tennessee River Basins.

The Red River Basin had the highest predicted concentrations because of the hundreds of thousands of cotton acres likely to need treatment and the relatively low volume of water flowing through the main trunk of the basin. Conversely, the Tennessee River Basin had the lowest predicted concentrations because of the high volumes of water present for dilution of insecticide runoff from the approximately 100,000 acres of cotton in the basin.

As previously mentioned, malathion had the highest predicted concentration, followed by azinphos-methyl, diflubenzuron, and methyl parathion, in decreasing order. The high solubility of malathion, its higher application rate (lb a.i./acre), and its intermediate adsorption constant support the predicted concentrations above levels estimated for the other insecticides.

Table B8-16. Maximum Predicted Insecticide Concentrations in the FLINT RIVER 7 Days After a 2-Year Storm

| River compartment | Eradication | | | | Suppression | | |
|---|---|---|---|---|---|---|---|
| | Malathion | Azinphos-methyl | Diflubenzuron | Methyl parathion | Malathion | Azinphos-methyl | Methyl parathion |
| **Water**: | | | | | | | |
| Total (mg/L) | 0.00173 | 0.000415 | 0.000105 | 0.000252 | 0.00152 | 0.000406 | 0.000211 |
| Dissolved (mg/L) | 0.00173 | 0.000415 | 0.000104 | 0.000250 | 0.00151 | 0.000406 | 0.000210 |
| Sediments (mg/kg) | 0.0156 | 0.00145 | 0.00353 | 0.0175 | 0.0136 | 0.00142 | 0.0147 |
| Biota (mg/g) | 1.52 | 0.155 | 0.305 | 0.0928 | 1.33 | 0.151 | 0.0778 |
| **Sediment**: | | | | | | | |
| Total (mg/L) | 0.00428 | 0.000510 | 0.000455 | 0.00627 | 0.00375 | 0.000500 | 0.00526 |
| Dissolved (mg/L) | 0.000422 | 0.000119 | 0.0000124 | 0.0000886 | 0.000370 | 0.000117 | 0.0000743 |
| Sediments (mg/kg) | 0.00380 | 0.000418 | 0.000422 | 0.00620 | 0.00333 | 0.000410 | 0.00520 |
| Biota (mg/g) | 0.370 | 0.0445 | 0.0364 | 0.0329 | 0.324 | 0.0436 | 0.0276 |

**Table B8-17. Maximum Predicted Insecticide Concentrations in the GILA RIVER 7 Days After a 2-Year Storm**

| River compartment | Eradication | | | | Suppression | | |
|---|---|---|---|---|---|---|---|
| | Malathion | Azinphos-methyl | Diflubenzuron | Methyl parathion | Malathion | Azinphos-methyl | Methyl parathion |
| **Water**: | | | | | | | |
| Total (mg/L) | 0.00922 | 0.00290 | 0.000438 | 0.000237 | 0.00314 | 0.00173 | 0.0000581 |
| Dissolved (mg/L) | 0.00921 | 0.00290 | 0.000436 | 0.000237 | 0.00314 | 0.00173 | 0.0000580 |
| Sediments (mg/kg) | 0.0826 | 0.0102 | 0.0148 | 0.0166 | 0.0282 | 0.00606 | 0.00406 |
| Biota (mg/g) | 8.08 | 1.08 | 1.28 | 0.0879 | 2.75 | 0.645 | 0.0215 |
| **Sediment**: | | | | | | | |
| Total (mg/L) | 0.0590 | 0.00842 | 0.00731 | 0.0165 | 0.0201 | 0.00502 | 0.00405 |
| Dissolved (mg/L) | 0.00582 | 0.00197 | 0.000200 | 0.000234 | 0.00198 | 0.00117 | 0.0000576 |
| Sediments (mg/kg) | 0.0523 | 0.00689 | 0.00678 | 0.0164 | 0.0178 | 0.00411 | 0.00401 |
| Biota (mg/g) | 5.10 | 0.733 | 0.584 | 0.0868 | 1.74 | 0.437 | 0.0213 |

Table B8-18. Maximum Predicted Insecticide Concentrations in the RED RIVER 7 Days After a 2-Year Storm

| River compartment | Eradication | | | | Suppression | | |
|---|---|---|---|---|---|---|---|
| | Malathion | Azinphos-methyl | Diflubenzuron | Methyl parathion | Malathion | Azinphos-methyl | Methyl parathion |
| **Water:** | | | | | | | |
| Total (mg/L) | 0.116 | 0.0255 | 0.00501 | 0.00325 | 0.117 | 0.0265 | 0.00320 |
| Dissolved (mg/L) | 0.116 | 0.0255 | 0.00500 | 0.00325 | 0.117 | 0.0265 | 0.00320 |
| Sediments (mg/kg) | 1.04 | 0.0893 | 0.170 | 0.227 | 1.06 | 0.0928 | 0.224 |
| Biota (mg/g) | 101.0 | 9.50 | 14.6 | 1.21 | 103.0 | 9.88 | 1.19 |
| **Sediment:** | | | | | | | |
| Total (mg/L) | 0.808 | 0.0851 | 0.0814 | 0.217 | 0.820 | 0.0885 | 0.214 |
| Dissolved (mg/L) | 0.0796 | 0.0199 | 0.00222 | 0.00301 | 0.0808 | 0.0207 | 0.00311 |
| Sediments (mg/kg) | 0.716 | 0.0697 | 0.0755 | 0.214 | 0.728 | 0.0724 | 0.211 |
| Biota (mg/g) | 69.9 | 7.42 | 6.5 | 1.14 | 79.9 | 7.71 | 1.12 |

**Table B8-19. Maximum Predicted Insecticide Concentrations in the SUNFLOWER RIVER 7 Days After a 2-Year Storm**

| River compartment | Eradication | | | | Suppression | | |
|---|---|---|---|---|---|---|---|
| | Malathion | Azinphos-methyl | Diflubenzuron | Methyl parathion | Malathion | Azinphos-methyl | Methyl parathion |
| **Water**: | | | | | | | |
| Total (mg/L) | 0.0286 | 0.00801 | 0.00150 | 0.000430 | 0.0273 | 0.00603 | 0.000440 |
| Dissolved (mg/L) | 0.0286 | 0.00801 | 0.00150 | 0.000429 | 0.0272 | 0.00603 | 0.000439 |
| Sediments (mg/kg) | 0.257 | 0.0280 | 0.0509 | 0.0300 | 0.245 | 0.0211 | 0.0308 |
| Biota (mg/g) | 25.1 | 2.98 | 4.38 | 0.159 | 23.9 | 2.24 | 0.163 |
| **Sediment**: | | | | | | | |
| Total (mg/L) | 0.0408 | 0.00565 | 0.00376 | 0.00706 | 0.0389 | 0.00425 | 0.0000724 |
| Dissolved (mg/L) | 0.00402 | 0.00132 | 0.000103 | 0.0000998 | 0.0383 | 0.000994 | 0.000102 |
| Sediments (mg/kg) | 0.0362 | 0.00462 | 0.00349 | 0.00699 | 0.0345 | 0.00348 | 0.00716 |
| Biota (mg/g) | 3.53 | 0.492 | 0.301 | 0.0371 | 3.36 | 0.370 | 0.0380 |

Table B8-20. Maximum Predicted Insecticide Concentrations in the TENNESSEE RIVER 7 Days After a 2-Year Storm

| River compartment | Eradication | | | | Suppression | | |
|---|---|---|---|---|---|---|---|
| | Malathion[a] | Azinphos-methyl | Diflubenzuron | Methyl parathion[a] | Malathion | Azinphos-methyl | Methyl parathion |
| **Water**: | | | | | | | |
| Total (mg/L) | 0.000358 | 0.000112 | 0.0000126 | 0.0000586 | 0.000461 | 0.0000897 | 0.0000799 |
| Dissolved (mg/L) | 0.000358 | 0.000112 | 0.0000126 | 0.0000584 | 0.000461 | 0.0000896 | 0.0000796 |
| Sediments (mg/kg) | 0.00321 | 0.000392 | 0.000426 | 0.00409 | 0.00414 | 0.000314 | 0.00557 |
| Biota (mg/g) | 0.314 | 0.0417 | 0.0367 | 0.0217 | 0.404 | 0.0334 | 0.0296 |
| **Sediment**: | | | | | | | |
| Total (mg/L) | 0.000573 | 0.0000927 | 0.0000320 | 0.000884 | 0.000737 | 0.0000742 | 0.00120 |
| Dissolved (mg/L) | 0.0000564 | 0.0000217 | 0.000000875 | 0.0000125 | 0.0000726 | 0.0000174 | 0.0000170 |
| Sediments (mg/kg) | 0.000508 | 0.0000759 | 0.0000297 | 0.000874 | 0.000654 | 0.0000608 | 0.00119 |
| Biota (mg/g) | 0.0495 | 0.00808 | 0.00256 | 0.00464 | 0.000637 | 0.00647 | 0.00633 |

[a] Results based on application of all insecticides taking 3 days.

# Appendix B

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# Appendix C

## Summary of Public Involvement

### Overview

In accordance with the National Environmental Policy Act (NEPA) (42 U.S.C. 432 et seq.) the Animal and Plant Health Inspection Service (APHIS) has solicited and assisted public participation in preparing this environmental impact statement (EIS). NEPA requires that agencies provide notice of hearings, public meetings, and the availability of environmental documents, so interested parties may be informed. The public can be involved in the NEPA process in two ways: scoping and the comment period. The scoping process takes place early in the NEPA process and helps the agency determine the scope of the issues that need to be addressed in the EIS. Any affected Federal, State, and local agencies, and other interested parties are invited to participate. The comment period occurs after the publication of the draft EIS and related supplements. During the comment period, an agency will solicit comments from Federal, State, and local agencies, and the public. The agency is required to assess and respond to all comments, and all substantive comments and their responses will be included in the final EIS.

### Scoping

The United States Department of Agriculture (USDA) APHIS provided notice (May 26, 1988, Notice of Intent, 53 FR 19010; July 22, 1988, Notice of Scoping Meetings, FR 27735) that an EIS would be prepared on the program to eradicate the boll weevil (*Anthonomus grandis*) from the United States. Comments and suggestions were solicited from Federal and State officials, environmental organizations, and other interested parties to aid in determining the scope of the EIS—the topics to be covered and the degree of detail necessary.

The scoping process helped APHIS to identify public and other agencies' concerns and to define the issues and alternatives that required detailed examination, while eliminating those of lesser concern. Also, the EIS was more efficiently prepared because the process encouraged coordination with cooperating agencies, identified important issues early, and helped project future scheduling needs.

Three scoping sessions were held in August 1988 to allow public comment on environmental issues involved in the cooperative boll weevil program. The first meeting was held on August 1, 1988, in Montgomery, Alabama. Later that week, similar meetings were held in Lubbock, Texas, and Phoenix, Arizona. The period for submitting written comments relating to the scoping of this EIS ended on September 3, 1988. APHIS received comments from many different public interest groups, including environmental organizations, growers' associations, concerned individuals, university entomologists, and State and local agencies.

APHIS considered all the comments and concerns expressed by the public during the scoping process when it formulated the boll weevil control alternatives and methods that are discussed in chapter 2 of this EIS. The selection of those alternatives and control methods and the assessment of impacts of the alternatives and control methods also reflect concerns that were stated during the scoping process.

The principal categories of concern that emerged during the scoping process were program design, environmental consequences, and economic and social concerns; these are summarized below. Though not all of the concerns are covered by the following list, all specific concerns were considered in preparing this final EIS.

### Program Design

The major concerns associated with program design fell into the following four areas:

1. The EIS should provide a balanced evaluation of all program alternatives, including a national eradication program, a systematic suppression program, conventional pesticide practices, and nonchemical alternatives. These programs should be evaluated in terms of efficacy, operational feasibility, and required technical resources.

2. Details about the program's operation should be identified, including procedures for supervision and task management; the system for investigating, reporting, and resolving complaints; education for the public and program personnel; and enforcement of mitigation measures. Long-term maintenance, verification, and environmental monitoring requirements also should be identified.

3. The need for a national program should be discussed, as well as the geographical progression of the national program, chronological duration needed to achieve eradication, and the effect of regional differences on program design.

4. The requirement for total grower support and participation should be discussed, as well as grower effect on the efficacy of the program.

### Environmental Consequences

Major concerns about environmental consequences were grouped into the following three areas:

1. The long-term and short-term consequences of all program alternatives should be discussed. This discussion should include an evaluation of the cumulative effects of program insecticides and the potential for a nationwide program to ultimately reduce insecticide use.

2. The potential impact on human health should be discussed, including an evaluation of the toxicity, carcinogenicity, and teratogenicity of the program insecticides.

3. The potential impact on nontarget species should be discussed, including potential impacts on wildlife, Federal- or State-listed endangered and threatened species, bees and other pollinators, and the potential of the program to affect populations of other cotton insect pests. The potential for environmental degradation of surface waters, groundwater, and the existing noise levels also should be addressed.

### Economic and Social Concerns

Economic and social concerns include the following three categories:

1. Program alternatives should be evaluated in terms of impact on farm economy, rural development, and community structure and community perceptions. The potential for pronounced public opposition should be identified.

2. The document should identify the potential for public and industry support of program alternatives.

3. The economic and social implications of cotton imports from Mexico and other countries should be addressed.

## Comments Received on the Draft EIS

The Notice of Availability for the draft EIS was published August 1, 1989 (54 FR 31710). The notice informed the public of the availability of the DEIS, requested comments, and gave notice of public meetings.

Comments were received from the public at meetings and by mail. Additionally, comments were invited from Federal, State, and local agencies with an interest in the boll weevil program and from those agencies with jurisdiction by law or special expertise regarding any issue that should be discussed in the EIS.

Public meetings were held in Phoenix, Arizona, on August 14, 1989; in Lubbock, Texas, on August 16, 1989; and in Montgomery, Alabama, on August 18, 1989. These meetings were conducted according to the procedure published in the Federal Register notice.

The public comment period, normally 60 days long, was extended 34 days to November 3, 1989 (54 FR 41859-41860, October 12, 1989) to allow all interested parties adequate time to comment. During the comment period, APHIS received comments from State and local agencies, public interest groups, university entomologists, and individuals.

In response to comments about the program in Alabama and comments about endangered, threatened, and proposed species, APHIS prepared a two-part supplement to the draft EIS: Implementation of the Program in Alabama, and Analysis and Protection of Endangered and Threatened Species. This supplement was available for public comment on July 29, 1991; the period for public comment ended on September 16, 1991. Many comments on the supplements came from those individuals or agencies who had submitted comments on the draft EIS. All

comments received on the supplements were used to make necessary revisions to the supplements (now appendices H and I) and the EIS.

Many of the comments received on the draft EIS and the supplement expressed similar areas of concern. These concerns were as follows: program feasibility, proposed alternatives, environmental effects, economic and social effects, and legal requirements. These concerns are summarized below. The following list does not contain all the comments received; however, all specific comments were addressed in preparing this final EIS. Specific comments and responses are presented in appendix D.

**Program Feasibility**

The major concerns about program feasibility fell into the following categories:

1. The EIS must accurately and thoroughly discuss the status of the program to date, including the success in current successful program areas. The numbers of weevils trapped in the previously eradicated areas should be included.

2. The ability of the boll weevil to migrate and move into new areas should be corrected. The possibility of the boll weevil overwintering and establishing itself on the High Plains in Texas should be included, as well as information on the boll weevil's ability to migrate long distances.

**Proposed Alternatives**

The concerns about the proposed alternatives were grouped into the following areas:

1. Alternatives to chemical controls need to be included in the EIS.

2. Reasons for not selecting suggested alternatives need to be more carefully explained.

**Environmental Effects**

The major concerns associated with environmental effects fell into the following categories:

1. Unknown risks involved with the use of chemical control methods need to be addressed more thoroughly. Additional information on inert ingredients, potential synergistic effects, and cumulative effects should be included.

2. The discussion of risks to nontarget species needs to be expanded. Information on the effects of the proposed chemical control methods on endangered and threatened species, pollinators, and the potential for cotton pest resistance should be included.

3. The hazard analyses for some of the proposed chemicals need to be clarified.

**Economic and Social Effects**

Concerns about economic and social effects fell into the following categories:

1. Additional data on the potential economic benefits from the program should be included in the EIS.

2. Social impacts on farmers who do not support the program should be examined.

**Legal Requirements**

1. The draft EIS does not comply with the Stipulation of Settlement. (Appendix I, the Implementation of the Program in Alabama, was designed to comply with the specifics of the Stipulation. This appendix was published for public comment on July 29, 1991, as a supplement to the draft EIS.)

2. Additional details on environmental mitigation (as described by the Council on Environmental Quality (CEQ) regulations on NEPA implementation) proposed by APHIS to mitigate any adverse environmental impacts need to be included in the EIS.

☆ U.S. Government Printing Office : 1991 - 311-364/40694

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